A HANDBOOK

FOR

SUPERINTENDENTS OF CONSTRUCTION, ARCHITECTS, BUILDERS, AND BUILDING INSPECTORS.

BY

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FIRST EDITION.
THIRD THOUSAND.

NEW YORK:
JOHN WILEY & SONS.
LONDON: CHAPMAN & HALL, LIMITED.
1905.

PRESS OF
BRAUNWORTH & CO.
BOOKBINDERS AND PRINTERS
BROOKLYN, N. Y.

PREFACE.

In preparing this volume it has been the aim of the author to prepare a book that will be an every-day help to any one engaged in building construction.

Building construction, like everything else, advances and changes with the times, and the author has tried to make this work as complete and up to date as possible. He does not claim credit for all the formulas and information given in this volume, some of it having been compiled from various authors and sources, a list of which will be given, and due credit is given to all for anything that is found compiled in this book from any other work.

Still there is enough original matter and information to be found in the following pages to make the author think that it will prove a valuable addition to any mechanical or technical library, and taken altogether it is as its title represents: A handbook for any one engaged in any branch of building construction, and most especially superintendents of construction, and inspectors.

If by his past experience as carpenter, contractor, architect, and superintendent of construction, and through the medium of this volume, the author is able to render any information or assistance to those engaged in building construction, he will feel himself amply repaid for the labor expended in preparing the following pages.

H. G. Richey.

WORKS AND AUTHORS CONSULTED BY THE AUTHOR IN PREPARING THIS VOLUME, AND OF WHICH LIST ANY WILL PROVE A VALUABLE ADDITION TO ANY LIBRARY.

Building Construction, by F. E. Kidder.

Architects and Builders' Pocket Book, by F. E. Kidder.

Treatise on Foundations, by W. M. Patton.

Inspectors' Pocket Book, by Austin T. Byrne.

Various Works of Fred T. Hodgson.

Bricklaying, by Owen B. Maginnis.

Hydraulic Cement, by Frederick P. Spaulding.

Civil Engineers' Pocket Book, by J. C. Trautwine.

Carnegie's Pocket Book, by Carnegie Steel Co.

National Tube Company's Pocket Book, by National Tube Company.

Mechanics and Engineers' Pocket Book, by C. H. Haswell.

Builders' Guide, by I. P. Hicks.

Stones for Building, by G. P. Merrill.

Steam, by Babcock and Wilcox.

Masonry Construction, by I. O. Baker.

Magazines from which information has been derived: *Architects and Builders' Magazine, Engineering News, Carpentry and Building, Brick Builder, Engineering Magazine, Scientific American, National Builder, Cement and Engineering News, Cement.*

Also catalogues and trade publications of the various manufactures.

The dates of the various building codes from which extracts have been taken are as follows:

New York	1901
Philadelphia	1903
Chicago	1903
Baltimore	1904
Cleveland	1904
San Francisco	1904
National Board of Fire Underwriters	1904

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A HANDBOOK FOR SUPERINTENDENTS OF CONSTRUCTION.

PART I.

PERSONALITY AND DUTIES OF A SUPERINTENDENT.

EXCAVATING, FOUNDATIONS, PILES, BUILDING-STONES.

Personality and Duties of a Superintendent.— A superintendent should be a man who can command the respect and obedience of those under him. In all his dealings he should be honest and just, demanding only what is right and insisting on what he demands being done. He should be a sober, upright, and intelligent man, well conversant with all the details of the work or structure which he will have under his supervision; he should study the work in advance so as to forestall any point or question which may come up for him to decide.

Before giving any decision or deciding any point he should study the matter carefully, be sure he is right, and then in a firm manner stick to it. Let a superintendent once give a decision and then by a little argument on the part of the contractor alter or change it and he will find the contractor will be sure to try to make him change others in the future.

At the commencement of any work or building the superintendent should be if anything a little more strict than necessary, for then he will have a chance to relax a little as the work progresses. This refers to both workmanship and material.

The superintendent should examine all material as it is brought to the work, and at once reject any that is of poor

quality or unfit for the work, and all rejected material he should have removed at once from the premises, for so long as any such material is at the job there is danger of some of it finding its way into the building or structure.

Regarding material the superintendent should be suspicious of any change or substitute advanced by the contractor, for it is of no advantage to a contractor to make a change unless it is to substitute something cheaper, and anything cheaper will be inferior in quality.

The superintendent should be at his post of duty at all hours when any work is being done, for there are some points of the work that in a few hours can be slighted enough to weaken the whole structure, and a building or any structure is only as strong as its weakest point.

In rejecting materials they should be marked and orders given to remove them at once. The superintendent should keep a record of all material rejected, giving the date and cause of rejection. He should be familiar with the tools used by the various trades and methods of using them, as he can then determine more quickly if a mechanic is doing good work or not. He should watch each and every workman employed so far as possible, and any whom he finds careless or unskilful, and whose work does not come up to the required standard, he should have removed.

The superintendent should keep a daily diary stating the condition of the work, state of the weather, materials received, or anything which has a bearing on the progress or completion of the work. He should see that the work progresses rapidly enough to insure its completion within contract time, and if there is any delay or suspicion of delay he should notify the contractor and report the same to his superiors.

On some work the superintendent is charged with the duty of making up the estimates due the contractor as the work progresses. To do this correctly it is advisable to obtain from the contractor at the commencement of the work a schedule of prices of the various parts of the work as he has estimated them. This should be given both in unit and in total. The superintendent in making up these estimates should be careful to do justice to both sides, being careful to give the contractor what is due him, but no more.

Of course on work where there are certain amounts to be paid at various stages of the work this schedule is not necessary,

as the amounts to be paid will be determined before the work is commenced.

If the superintendent would have a cost or price book and keep memoranda of the cost of the various works upon which he is engaged it will be a great help to him in making any estimate of work.

The superintendent should study the drawings and specifications carefully in advance of the work, so as to determine if everything is working out correctly, as there are often little changes or questions which will come up as the work progresses which the superintendent will be called upon to decide, and if he keeps on the lookout for such things he will have time to consult with his superiors before rendering a decision to the contractor.

Contractors in different localities have different methods of executing work, and it is advisable to leave the mode of execution to the contractor so long as the desired end is obtained, viz., a perfect and acceptable job.

The plans and specifications are his guide and he should insist on strict compliance with their meaning. He should avoid any arguments or controversy, as his duty is only to see that the work is carried out according to the meaning of the plans and specifications, and not to decide if any other method or material is better. When he has any complaint to make he should make it at once and in a firm, gentlemanly manner, and insist on its settlement immediately.

Any superintendent who acts in this manner and who has had experience enough to make himself familiar with good construction and methods of executing work should have no trouble with any one who is doing work under his supervision.

When the superintendent has cause to submit materials to a laboratory for testing, the following amount of each material should be submitted to make a complete test:

Cement.	not less than 15 pounds
White lead.	" " " 2 "
Red lead.	" " " 2 "
Varnish.	" " " 1 quart
Oil.	" " " 1 "
Shellac.	" " " 1 "
Tin.	3 whole sheets
Copper or zinc. ..	pieces $6'' \times 6''$

Laying Out for Foundations, etc.—The superintendent should have the contractor or his representative do all the laying out, so that he will be responsible for all errors, but the superintendent should go over all lines, angles, and measurements and verify them as to being correct.

In laying out work, turning angles, or running lines or levels it is advisable to do so with a transit and level, and if the superintendent does not possess or understand the use of one of these instruments he should engage the services of a civil engineer. A convertible architect's level, manufactured by Keuffel & Esser Co. of New York, is a good instrument for a superintendent to possess, as with it he can do all work such as running lines, giving levels, and bench-marks that may be desired.

Fig. 1 shows how the batter-boards should be set for the lines of a foundation; the boards should be long enough to catch the lines for both inside and outside of all walls and footings. The lines shown in the cut represent the lines in place for the walls and piers.

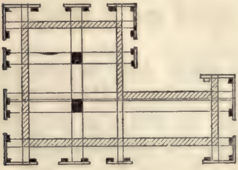


Fig. 1.

These boards should be put up firm and well braced and placed far enough back from the excavation to insure their being in solid ground; they should also be made high enough for the wall to be built up to the belt course, or ashlar course, without disturbing them. After the batter-boards are set the superintendent should have the main lines stretched and try the distance from opposite corners to prove if they are laid out square. A level or bench-mark should be put up on a solid stake or other solid object, giving the height of a certain point in the height of the walls or building; then all other heights can be measured from this point.

As the different grade heights are usually given in decimal parts of a foot from a given point a table giving the various fractions in feet and inches will be found very useful; such a table will be found on pages 608 and 609.

After the building is up, say to the belt course or any other level course, it is advisable to have the foreman of the building prepare a pole giving the heights of the various points or courses in the building, and set them all to this pole; in this way after the first course is set and levelled, if all the other courses are

set to this pole they will be correct for height and level. See Fig. 83, page 66.

The superintendent should go over the drawings as soon as possible after the work is commenced and see that all measurements are marked correct, as a little error in marking sometimes makes a lot of trouble afterwards. The author knows of an instance where the foreman of a building staked it out and built it two feet shorter in length than the plans called for, yet it was never noticed by the superintendent simply because he did not take the trouble to verify the foreman's measurements in laying out the building.

In laying out work where a series of points come on the same line the tape should be stretched the full length and the location of each point marked by adding together the various distances from the starting-point.

In giving any point, such as a bench-mark or height, or measurement of any kind, the superintendent should be very careful and be sure he is correct, for he can be held responsible for any error he may make.

In running walls, piers, etc., through from story to story the superintendent should always check them up at each floor-level to see if they are being carried up plumb.

Excavating.—When the excavating is being done the superintendent should see that all excavations, trenches, etc., are dug out at least six inches larger than the walls, so that there will be room for pointing or cementing, or when concrete is to be used, to have room for building the wood forms.

The superintendent should give height or bench-marks and see that the excavating is carried to the proper level, and if by chance any trench for a footing-course is dug too deep he should have it filled up with concrete or masonry, and not with loose earth.

If a stream of water or spring is encountered, provision must be made to take the water away; this can be done with a broken-stone or open tile drain as shown by Figs. 2 and 3.

As soon as the excavation is dug to the proper depth the superintendent should have the sewer to the building run in past the inside of the wall and a strainer put on so as to carry off any water which may gather from rain, snow, or damp soil.

The superintendent should pay strict attention to the work during the putting in of the foundation-footing and walls, for

there is a tendency on the part of some contractors to slight this work, thinking it will soon be covered up.

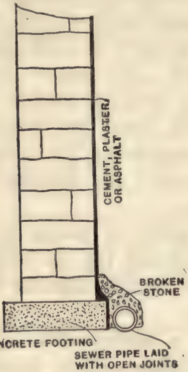


FIG. 2.

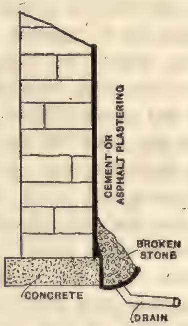


FIG. 3.

Shrinkage of Excavated Material.—All materials when first excavated will increase in bulk, but after laying a while will, with the exception of rock, shrink until they will occupy less space than when originally in the earth.

The shrinkage of various materials has been estimated as follows:

Gravel	8	per cent
Gravel and sand	9	"
Clay and clay earths	10	"
Loam and light sandy earths	12	"
Loose vegetable soils	15	"
Puddled clay	25	"

Foundations.—One of the first duties of a superintendent after taking charge of the erection of a building or other structure is to determine the stability of the ground upon which it will rest. The architect should ascertain if possible the nature of the ground before he makes his plans, as then his foundations can be made to suit the material it will rest upon. But often this is not done, and it devolves upon the superintendent to test the stability of the ground, and when it is found not to have a sufficient carrying capacity changes will have to be made in the foundation of the structure. If there is

any other like building in the immediate vicinity already erected the superintendent should make inquiry of the architect and builder of this building and find out all he can as to the nature and formation of the ground, and if any difficulty was experienced in putting in the foundations of the building.

Testing the Soil.—After the excavation is made, if the superintendent has any doubt as to the stability or carrying power of the ground on which the foundations will rest, he should test the same by boring holes or sinking a shaft, and if the bed is found insecure he should at once consult with his superiors and determine if the excavations are to be carried deeper or the plans of the foundation-walls changed so as to obtain a greater breadth or surface resting on the ground. There should be several borings made in different parts of the excavation to about the same depth (10 to 15 feet is deep enough for ordinary tests) and if the character of the soil is about the same in all the holes this test will be sufficient, but if there is a decided difference in the borings of any of the holes as to material, depth of stratas, etc., it is advisable to sink other holes to make a complete test.

It is better to have a little expense at the commencement of a building or other structure to determine the stability of the

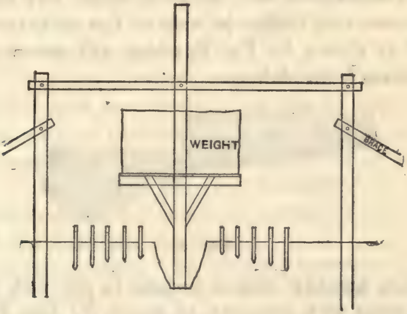


FIG. 4.

foundation than to go ahead and erect the structure and have the walls crack or perhaps worse from unequal settlement. Like a chain, a building is only as strong as its weakest point.

After testing the soil by borings as described, if there should be any doubt at all as to its carrying capacity it should be tested by an actual experiment as to what it will carry. This

can be done by digging a hole and setting up a mast as shown by Fig. 4.

The mast should be set up as shown and braced at the top to four posts which must be braced firm and secure as shown. A platform should be built on the mast to carry the load. Before loading, stakes should be driven radiating from the mast out about four feet, and the tops made perfectly level, and then a level should be taken from them to the mast. Now after the load is put on, a straight edge will show if the top of the stakes remains in line or if there has been any upheaval. Then a level should be taken of the mast to see if it has settled any.

Bed of Foundations.—The superintendent should see that the surface of the foundation-bed is dressed off at right angles to the thrust or weight which is to bear upon it. Where possible all foundations should be carried around at the same level, but where this is impossible and the footings have to be put in at unequal depths the difference in height of the different levels should be made in perpendicular steps as shown by Fig. 5.

Fig. 5.

Where the foundations rest on rock which has an incline or dip of not over two inches in a foot, the rock can be cut or roughed off as shown by Fig. 6, which will prevent the building or structure from sliding.

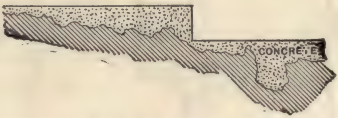


Fig. 6.

Where there are any rifts or fissures in the rock they should be entirely filled with concrete, as shown by Fig. 7, or if very deep, should be arched over with a masonry or concrete arch or with I beams bedded in the concrete.

Rock.—Where rock is used as a foundation-bed the superintendent should see if there is any seepage or water; as is often the case the water will follow along the top of the rock and come out in the excavation. In such cases care must be taken to collect the water and dispose of it, or by putting a drain

outside of the walls, catch the water and carry it away before it enters the excavation. Rock is of course the best foundation that can be had to build upon, as there will be no doubt of its carrying power, and as the crushing strength of the weakest

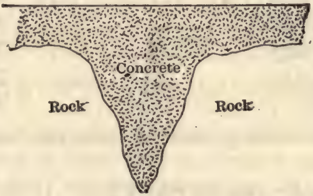


FIG. 7.

sandstone is about 3000 pounds to the square inch, a foundation of rock will carry all that is likely to be built on it.

GRAVEL.—This is one of the best materials to build on, but, like sand, has to be confined to a certain extent, especially if there is any water present, as there will be a tendency to wash out the sand and fine gravel, but if there is no water present and the gravel is packed solid it will carry the heaviest of structures.

SAND.—Sand makes a good foundation to build on only when it is confined on all sides, and is very dangerous to build on unless it is so confined that there will be no danger of water penetrating and undermining it.

CLAY.—This is an excellent material for a foundation providing it is solid, free from water, and has no large seams which will let the water penetrate. A clay foundation should be tested thoroughly if there is any doubt as to its not being solid and dry, for some clays are very deceptive. If there are any seams through which the water can penetrate, there will be great danger of the structure slipping.

SILT AND SOFT SOILS.—No building operation of any magnitude can be erected on these materials unless an artificial foundation is provided by driving piles, putting in footings of timbers or beams and concrete so as to cover a large surface and distribute the weight, or by sinking caissons and filling them with concrete.

The table given below will form a guide as to the bearing power of soils, etc. But, after all, there is no definite rule except by experience and testing.

Name of Soil, etc.	Carrying Power per Square Foot.
Rock, hard, on native bed	250 tons
Ledge rock	36 "
Hard-pan	8 "
Gravel	5 "
Clean sand	4 "
Dry clay	3 "
Wet clay	2 "
Loam	1 ton

Regarding the bearing power of soils, etc., the Chicago Building Law says:

Sec. 75. *Load for Clay* 15 *Feet Thick.*—If the soil is a layer of pure clay at least 15 feet thick, without admixture of any foreign substance excepting gravel, it shall not be loaded more than at the rate of 3500 pounds per square foot. If the soil is a layer of pure clay at least 15 feet thick and is dry and thoroughly compressed, it may be loaded not to exceed 4500 pounds per square foot.

Sec. 76. *Load for Sand* 15 *Feet Thick.*—If the soil is a layer of dry sand 15 feet or more in thickness, and without admixture of clay, loam, or other foreign substance it shall not be loaded more than at the rate of 4000 pounds per square foot.

Sec. 77. *Load for Mixed Soil.*—If the soil is a mixture of clay and sand, it shall not be loaded more than at the rate of 3000 pounds per square foot.

Sec. 78. *Foundations in Wet Soil—Trenches to be Drained.*—In all cases where foundations are built in wet soil, it shall be unlawful to build the same unless the trenches in which the work is being executed are kept free from water by baling, pumping, or otherwise until after the completion of work upon the foundations.

Sec. 79. *Foundation — Where not Permitted.* — Foundations shall not be laid on filled or made ground, or on loam, or on any soil containing admixture of organic matter.

Piles for Foundations.—Piles are used to a great extent for the foundations of structures which rest on a soft or wet soil, and the superintendent should be familiar with the methods of driving and using them.

Material.—Oak is the best wood for piles, but is not used much on account of its scarcity in some localities and its value for other purposes, which makes the cost too excessive for piling. Spruce, Norway pine, and Oregon pine make good piles.

Cypress is sometimes used, but it is not hard enough to stand driving. The superintendent should inspect each and every pile as it is brought to the work and any rejected ones should be so marked and removed at once.

The following specifications for wood piles and timber were prepared by the American Railway Engineering and Maintenance of Way Association and is very complete.

SPECIFICATIONS FOR PILES AND TIMBER.

Piles.—All piles of whatever kind shall be cut from growing trees, free from wind or heart shakes, large or unsound knots, decay or other defects which would impair the strength or durability of the pile. Only butt cuts, cut about the ground swell of the tree, and with both ends cut square, will be accepted. They shall be peeled of bark and the knots trimmed, and the specified sizes shall be, after peeling, straight and uniformly tapering.

Oak Piles.—Shall be of the variety of white, burr, or post oaks, with wood of close, firm grain and with a sap ring not over 2 ins. thick. They shall be not less than 12 ins. diameter at 6 ft. from the butt, and when 28 ft. or less in length they shall be 10 ins. diameter at the top or small end, and where 30 ft. in length or longer shall be not less than 9 ins. at the top.

Norway Pine and Tamarack Piles.—These shall not be less than 14 ins. nor more than 18 ins. diameter at the butt, and where 36 ft. or less in length shall be not less than 10 ins. in diameter at the top, and where over 36 ft. in length shall not be less than 9 ins. at the top.

Long-leaf Pine Piles.—These shall be strictly long-leaf Southern or yellow pine, and no doubtful grades will be accepted. They shall be hewed square, with all the sap removed. They shall be not less than 12 ins. or more than 14 ins. square at the large end, or 8 ins. square at the small end, and must be smoothly hewed without large or deep score hacks.

Cedar Piles.—These shall be of white or red cedar. White-cedar piles shall be not less than 14 ins. diameter at the butt and 9 ins. at the top where less than 30 ft. in length. Where over 30 ft. in length, they shall be not less than 8 ins. diameter at the top. Unsound butts will be accepted if the defect is not more than 5 ins. in diameter, and there must be at least 5 ins. of sound wood all around the defect. Red-cedar piles shall be not less than 12 ins. at the butt and 8 ins. at the top.

TIMBER.—All timber of whatever variety shall be cut from sound live trees, and shall be sawed full size, square in section and out of wind. It shall be free from wind shakes, large or unsound knots, pitch seams, decay or any other defects which would impair its strength and durability, and shall generally be free from sap.

LONG-LEAF PINE.—This shall be of the variety known as long-leaf Southern or yellow pine, and no loblolly or other doubtful grades will be accepted. The wood must be close, firm grained, and free from red heart or red-heart streaks; sound knots not over $1\frac{1}{4}$ ins. diameter will be allowed, but knots must not be in groups. Sap wood will be allowed on one or more of the four sides to an extent of not more than 15 per cent of the surface of any one side, and at any one point throughout the length of the piece.

FIR.—This shall be of the variety of Douglas fir, sometimes called Oregon or Washington fir, and may be the yellow or red variety, preferably the first. It shall not have at any point of its length and at any edge sap wood more than 2 ins. in width, and shall be free from knots over $1\frac{1}{2}$ ins. diameter, except that in long stringers sound knots not over $2\frac{1}{2}$ ins. diameter will not be cause for rejection if not more than 4 ft. from the end.

POINTING.—In silt and very soft soils, piles are usually driven with a square end, but in the harder soils they will have to be pointed, and in some cases provided with an iron shoe. There are several kinds of these shoes made, but those which are made with a socket and flat surface for the pile to set on will drive the best and not be so liable to split the pile as

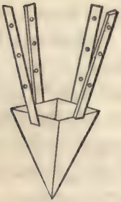


FIG. 8.

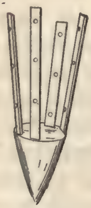


FIG. 9.

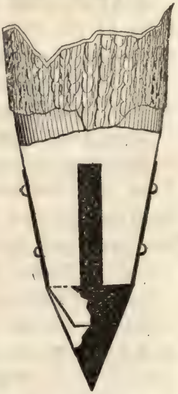


FIG. 10.

some others. Figs. 8, 9, 10 show very good styles of shoes and ones that will drive well.

Driving.—When the piles are being driven the superintendent should see that the large end is cut off square so that the hammer will strike it square and solid; he should see that rings are used on the head of the pile to keep it from splitting or brooming. It is customary in driving piles to lay the ring on the top of the pile and let the hammer at the first blow sink the ring into the wood. This is all right, providing the ring is nearly as large as the pile, but if a small ring is used in this way it causes large layers or splinters to split off the pile five or six feet in length. The superintendent should see that rings of different sizes are used or have the head of the pile chamfered off to suit the ring. A patent cap shown in Fig. 13 is now taking the place of rings in driving as shown. It is made to fit over the top of the pile B and is lifted with the hammer after the pile is driven. Before driving, the pile should be stripped of all the bark, as it has a tendency to promote decay.

The superintendent should see that the bottom end of the piles are perfectly square if they are being driven with a square end, or if pointed, see that the point is made true and in the centre of the pile; if the point is not true or the end not square it will cause the pile to glance when being driven.

Piles when driven in salt water should be thoroughly impregnated with creosote or some other preservative to protect

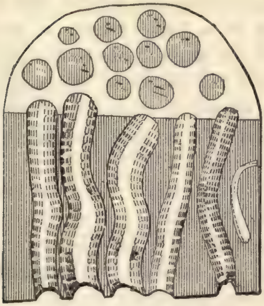


Fig. 11.

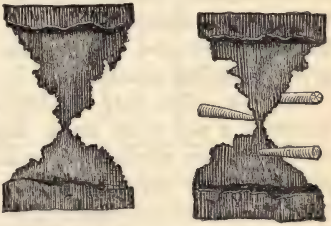


Fig. 12.

them from the ravages of the teredo. The life of a pile where exposed to these mollusks is from three to five years, and when

impregnated with a preservative it lengthens their life about three years. Fig. 11 shows the appearance of a pile eaten by the teredo, and Fig. 12 shows a pile eaten off by limnoria.

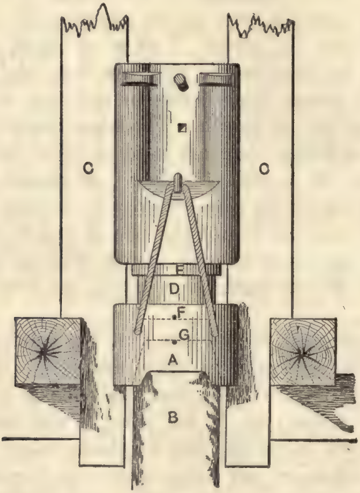


FIG. 13.

During the driving of piles the superintendent should watch the penetration at each blow, and if a hard strata is encountered and the pile drives hard he should have the lift of the hammer reduced and a shorter fall given or there will be danger of splitting the pile. He should keep a close lookout for short piles and see that each pile is long enough to give the desired penetration.

TESTING.—The only reliable way to ascertain the carrying power of a pile is by actual experiment with a pile driven in the foundation where they are to be used. To do this several piles should be driven in the foundation and four of them left up high enough to build a platform on, as shown in Fig. 14. The platform should then be evenly loaded with the desired weight or until the piles move. In this way a reliable test can be made, and where a structure of any importance is to rest on a foundation of piles the superintendent should insist on a complete test being made.

The following table and formula taken from *Engineering News* has been used by a number of engineers and has been pronounced

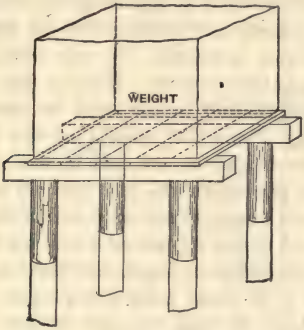


FIG. 14.

very reliable. The table is for spruce piles and average penetration during last five blows of a 1200-pound hammer dropping 15 feet.

BEARING VALUE OF PILES.

Nature of Soil.	Length of Pile in Feet.	Average Diameter in Inches.	Penetration in Inches.	Load in Tons.
Silt	40	10	6	2.75
Mud	30	8	2	6
Soft earth with boulders and logs	30	8	1.5	7.2
Moderately firm earth or clay with boulders and logs	30	8	1	9
Soft earth or clay	30	10	1	9
Quicksand	30	8	.5	12
Firm earth	30	8	.5	12
Firm earth into sand or gravel	20	8	.25	14
Firm earth to rock	20	8	0	18
Sand	20	8	0	18
Gravel	15	8	0	18

The formula is:

$$\text{Safe load in pounds} = \frac{2WH}{S+1},$$

in which W equals weight of the hammer in pounds, H its fall in feet, S average penetration in inches during last five blows.

The following from the New York building code will be a good guide for the superintendent:

"Sec. 25. No pile shall be used of less dimensions than 5 inches at the small end and 10 inches at the butt for short piles, or piles 20 feet in length, and 12 inches at the butt for long piles, or more than 20 feet in length. No pile shall be loaded with a load exceeding 40,000 pounds. When a pile is not driven to refusal, its safe sustaining power shall be determined by the following formula: Twice the weight of the hammer in tons multiplied by the height of the fall in feet divided by least penetration of the pile under the last blow in inches plus one."

There have been cases where piles which were driven for a railroad trestle and which supported a moving load were driven in sand and gravel, and to a depth and resistance which figured an ultimate load of 60 tons; after a few weeks of use under an engine load of about 30 tons the piles settled. This no doubt was caused by the vibration, and the piles resting on a wet sand or gravel caused the water to collect and act something like a water jet, thus causing the piles to settle. Thus it will be seen that there are cases where no formula will give definite results, and this is where the superintendent must use good judgment in testing a pile and its foundation.

Concrete Piles.—Concrete piles are now being used with good success. One form of pile, Fig. 15, is made by casting the concrete and reinforcing it with steel. After they are thoroughly set and dry they are driven like an ordinary pile, except a special cap is used to prevent shattering the head of the pile. Another type called the Raymond, Fig. 16, has been used, which consists of a thin shell of metal with a strong core inside to take the shock of driving; after the shell and core are driven to the desired depth, the core, which is collapsible, is withdrawn and the shell filled with concrete. These piles are usually made with a large taper, as this gives them a large bearing area and permits the core to be taken out easily; about 6 inches at the bottom and 20 inches at the top is the usual size. By a test made in Chicago, one of these piles carried as much as three wooden ones having the same diameter at the point. And at Schenectady, N. Y., they were loaded with from 32,000 to 48,000 pounds per pile without settlement. The soil was a soft fill.

Figs. 17 and 18 show what is known as the Simplex Pile. A wrought-iron or steel cylinder with a concrete point is driven

like any ordinary pile, then the reinforcing is put inside the shell and it is filled with concrete, the shell being drawn as the concrete is filled up.

There have been used in the building of the wharves in San Francisco harbor concrete piles made by forcing down a shell

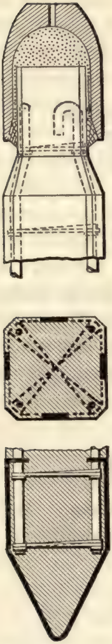


FIG. 15.

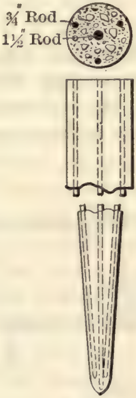


FIG. 16.

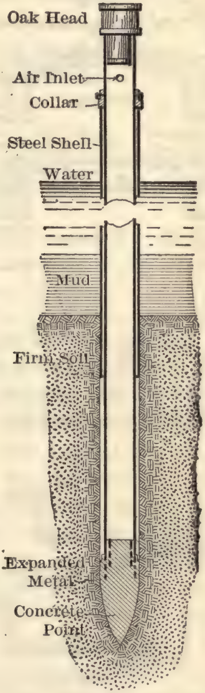


FIG. 17.

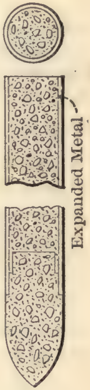


FIG. 18.

of wood 2 to 3 feet in diameter and after pumping it out filling it with concrete. The wooden shell is left on and by the time it decays or the teredo has destroyed it the concrete is hard and a concrete pile is the result. (See page 165 as to mixing concrete, etc.)

Steel Sheet-piling.—Fig. 19 shows a section of a sheet-piling made by the Friestedt Interlocking Channel Bar Co. of

Chicago; the piling is built up of channels and Z bars and locks together as driven.

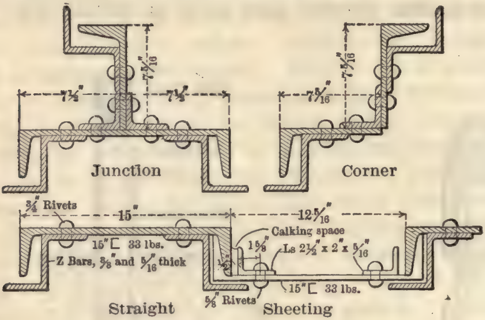


FIG. 19.

Another type of sheet-piling shown by Fig. 20 is manufactured by the H. Wittekind Interlocking Metal Piling Co. Piles of this kind are valuable for use in foundation-work, as they can be driven around the space to be excavated and the

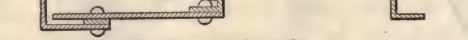


FIG. 20.

interior then taken out, the piling holding up the embankment and tending to keep out any water.

Fig. 21 shows a new style of steel sheet-piling which has recently been introduced, in which each pile is a single piece, complete in itself without rivets, bolts, or other attachments. The piles are of a special rolled section, consisting of a flat web with a cylindrical rib on each edge, the outer end of each rib

being slotted, as shown in the accompanying cut. The ribs are not of the same diameter, but the smaller rib of one pile fits easily within the larger rib of the adjacent pile, while the slot admits the web. This allows some flexibility in changing the direction of the line of piling, but for turning corners there is a special section of pile having the web bent in a curve or at an angle. The joints can be made water-tight by packing them with suitable material. The cut shows piles for a spacing of 12 inches, weighing 40 pounds per foot, but they are rolled in several sizes, according to the length and character of the work.

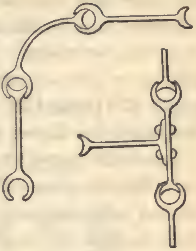


FIG. 21.

This form of sheet-piling is the invention of Mr. Samuel K. Behrend, and is manufactured and sold by the United States Steel Piling Co., 135 Adams Street, Chicago.

Capping of Piles.—After the piles are driven, the superintendent should see that they are cut off below low-water line. They should be cut off level and on a line so that the capping will have a true and equal bearing on each pile.

WOOD-CAPPING, OR GRILLAGE.—Where wood-capping is used the piles must be cut off low enough so that the timber in the grillage will be below low-water line, otherwise it will decay. The timbers are usually laid longitudinally on top of the piles and these timbers in turn crossed with short timbers, forming a floor to start the masonry on. In putting in these timbers the superintendent should pay close attention to see that the timbers have a bearing on each and every pile and are fastened to them with long drift bolts. The timbers should be strictly No. 1, free from any decay or other imperfection.

STEEL GRILLAGE. — Steel beams are used extensively for capping, being bedded in concrete; where they are used, the superintendent should see that the beams rest on each and every pile and that the beams are heavily coated with asphalt, or that concrete or cement mortar is put around them in such a manner that the beams will be thoroughly coated with cement, otherwise they will rust.

CONCRETE CAPPING.—Concrete, which is much used for capping of piles, is one of the best materials for this purpose, for when it is put in properly it forms one continuous stone having

a solid bed on all the piles. The superintendent should see that the piles are cut off square and the dirt cleaned away so the concrete can be rammed around the top of the pile to a depth of a foot or more. He should also pay strict attention to the mixing of the concrete and the ramming of it as described on pages 174 and 178, as this work is very often slighted unless the workmen know there is some person watching them.

Concrete capping is very often reinforced with steel beams or railroad rails. These should be free from rust or dirt and coated with asphalt, or close attention given to covering them with a coat of cement mortar or concrete. If the concrete is rammed solid enough around the beams it will in itself form a protection, but this takes much care and time and will require the strict attention of the superintendent. The New York building code says:

"The tops of all piles shall be cut off below the lowest water line. When required, concrete shall be rammed down in the interspaces between the heads of the piles to a depth and thickness not less than 12 inches and for 1 foot in width outside the piles. Where ranging and capping timbers are laid on the piles for foundations, they shall be of hard wood not less than 6 inches thick and properly joined together, and their tops laid below the lowest water line. Where metal is incorporated in or forms part of the foundation it shall be thoroughly protected from rust by paint, asphaltum, concrete, or by such materials and in such manner as may be approved by the Commissioner of Buildings. When footings of iron or steel for columns are placed below the water level, they shall be similarly coated or enclosed in concrete for preservation from rust."

When concrete is used for capping it should be allowed to harden before any additional weight is built upon it, or the ground may give between the piles and the piles will act like a series of punches forcing their way up through the concrete.

Granite Capping.—When granite capping is used the superintendent should see that the piles are driven in such a manner and the granite blocks are of such a size that a stone will not rest on more than three piles, as it is hard to get a stone to rest evenly on more, as shown by Fig. 22.

The superintendent should see that the bottom bed of the stones is cut true, and in setting them it is well to put a bed of strong cement mortar on top of the piles, as this will insure

a solid bearing on each pile. The granite blocks should be of such sizes that they will break joints as much as possible, as shown by Fig. 22. On top of this capping the footing-course

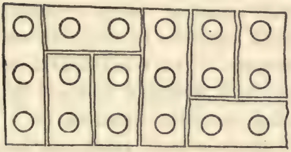


FIG. 22.

FIG. 23.

should be laid, each stone extending beyond the lines of the wall as shown by Fig. 23.

SPREAD FOOTINGS.—In many instances the footings of a structure have to be spread or extended out so as to cover ground enough to insure the carrying of the building, and in some cases the entire area of the foundation is covered with a grillage of steel or iron beams bedded in concrete. The superintendent should see that the surface of the foundation which it is intended to cover is carefully levelled off and the concrete laid in layers of not more than 8 inches in thickness, and that the beams are coated with asphalt or covered with cement. It has been demonstrated that iron or steel bedded in concrete, where the iron or steel was completely covered and the cement and iron in contact at all points, that the iron or steel will not rust. Only the best Portland cement and clean sharp sand should be used for this work. See page **168**.

The Chicago Building Law says: "If steel or iron rails or beams are used as parts of foundations, they must be thoroughly imbedded in a concrete the ingredients of which must be such that after proper ramming the interior of the mass will be free from cavities. The beams or rails must be entirely enveloped in concrete, and around the exposed external surfaces of such concrete foundations there must be a coating of a standard cement mortar not less than 1 inch thick."

The foundation should be prepared by first laying a bed of concrete to a depth of from 4 to 12 inches and then placing upon this a row of I beams at right angles to the face of the wall. In the case of heavy piers the beams may be crossed in two directions. Their distances apart, from centre to centre,

may vary from 9 to 24 inches, according to circumstances, i.e., length of their projection beyond the masonry, thickness of concrete, estimated pressure per square foot, etc. They should be placed at least far enough apart to permit the introductiou of the concrete filling and its proper tamping between the beams. Unless the concrete is of unusual thickness, it will not be advisable to exceed 20-inch spacing, since otherwise the concrete may not be of sufficient strength to properly transmit the upward pressure to the beams. The most useful application of this method of founding is in localities where a thin and comparatively compact stratum overlies another of a more yielding nature. By using I beams in such cases, the requisite spread at the base may be obtained without either penetrating the firm upper stratum or carrying the footing courses to such a height as to encroach unduly upon the basement room.

I Beams as Used in Foundations.—METHOD OF CALCULATION.—The following cuts and tables which have been prepared by The Carnegie Steel Co. give the strength and safe projection of beams used in foundations and footings. The same precautions should be taken with these beams as described on page 19.

The known quantities in this calculation are the load (L) on the column in tons, the allowable bearing capacity per square foot of ground in tons (b), and the projections p, p', p'' in feet for the various tiers of beams.

Figure the separate areas covered by the successive tiers of beams and divide the load on the column by these areas. The quotients will give their respective pressures b, b', b'' per square foot. Assume any spacing in inches, generally greatest for the lowest tier of beams and about 9 inches for the top course.

Find the corresponding figure for such spacing and pressure in the table on page 23 and multiply it by the corresponding projection. This product will give the modulus M.

In the table of moduli find the beam corresponding to this product.

For any other spacing or pressure than those given find M from the formula $M = p\sqrt{\frac{sb}{12}}$.

$$\left.\begin{array}{r} \textit{Example.}\text{—Let } L = 588 \text{ tons} \\ \text{Let } b = 3 \text{ tons} \end{array}\right\} \begin{array}{l} \text{Assume } p = 3 \text{ ft. } 6 \text{ in., } p' = 5 \text{ ft.} \\ \quad 3 \text{ in., } p'' = 1 \text{ ft. } 9 \text{ in.} \\ \text{Then } b' = 6 \text{ tons and } b'' = 24 \text{ tons.} \end{array}$$

Use 15 in. spacing for lowest tier of beams.
" 12 " " " 2d " " "
" 9 " " " 3d " " "

Now using the above method of calculation we have for the respective tiers:

$3.5 \times 1.937 = 6.78 =$ mod. corresponding to 12-in. 31.5-lb. beam.
$5.25 \times 2.450 = 12.86 =$ mod. corresponding to 20-in. 75-lb. beam.
$1.75 \times 4.243 = 7.43 =$ mod. corresponding to 12-in. 40-lb. beam.

TABLES GIVING THE SIZE AND WEIGHT OF BEAMS FOR $s=$ 9, 12, 15, 18, 24 INCHES, $b=1$ TO 50 TONS PER SQUARE FOOT, AND $p=$ VARIABLE IN FEET.

Depth of Beam in Inches.	Weight per Foot.	Moduli.	Depth of Beam in Inches.	Weight per Foot.	Moduli.
24	100	16.263	12	50.00	8.210
24	90	15.772	12	40.00	7.730
24	80	15.231	12	35.00	7.122
20	100	14.858	12	31.50	6.925
20	90	14.412	10	40.00	6.505
20	80	13.983	10	30.00	5.982
20	75	13.007	10	25.00	5.706
20	65	12.488	9	35.00	5.755
18	70	11.683	9	25.00	5.220
18	60	11.168	9	21.00	5.016
18	55	10.857	8	25.50	4.776
15	100	12.653	8	20.50	4.494
15	90	12.259	8	18.00	4.354
15	80	11.892	7	20.00	4.009
15	75	11.085	7	15.00	3.715
15	70	10.862	6	17.25	3.412
15	60	10.405	6	12.25	7.112
15	55	9.532	5	14.75	2.842
15	50	9.270	5	9.75	2.539
15	42	8.861	4	10.50	2.182
12	55	8.445	4	7.50	1.994

Tons per Square Foot.	Spacing of I Beams.				
	9″	12″	15″	18″	24″
1	0.866	1.000	1.118	1.225	1.414
2	1.225	1.414	1.581	1.732	2.000
3	1.500	1.732	1.937	2.121	2.450
4	1.732	2.000	2.236	2.450	2.829
5	1.936	2.236	2.500	2.738	3.162
6	2.121	2.450	2.739	3.000	3.464
7	2.291	2.646	2.958	3.240	3.742
8	2.450	2.828	3.162	3.463	4.000
9	2.598	3.000	3.354	3.674	4.243
10	2.738	3.162	3.536	3.872	4.472
11	2.872	3.317	3.708	4.061	4.690
12	3.000	3.464	3.873	4.242	4.899
13	3.122	3.606	4.031	4.415	5.099
14	3.240	3.742	4.184	4.582	5.292
15	3.354	3.873	4.331	4.743	5.477
16	3.464	4.000	4.472	4.898	5.657
17	3.571	4.123	4.610	5.050	5.831
18	3.674	4.243	4.744	5.196	6.000
19	3.775	4.359	4.874	5.338	6.164
20	3.873	4.472	5.000	5.477	6.325
21	3.969	4.583	5.124	5.612	6.481
22	4.062	4.690	5.244	5.744	6.633
23	4.153	4.796	5.362	5.873	6.783
24	4.243	4.899	5.477	6.000	6.928
25	4.330	5.000	5.591	6.123	7.071
30	4.743	5.477	6.124	6.707	7.746
35	5.124	5.916	6.615	7.245	8.366
40	5.477	6.325	7.071	7.746	8.945
45	5.810	6.708	7.500	8.215	9.487
50	6.124	7.071	7.906	8.660	10.000

I Beams Used in Wall Foundations.—METHOD OF CALCULATION:

Let $L=$ weight of wall per lineal foot in tons and
$b=$ assumed bearing capacity of ground per square foot (usually from 1 to 3 tons);

then $\frac{L}{b} = W =$ required width of foundation in feet;

$w =$ width of lowest course of footing-stones;

$p =$ projection of beams beyond masonry in feet;

$s =$ spacing of beams centre to centre in feet.

Evidently the size of beams required will depend upon their strength as cantilevers of a length p sustaining the upward reaction, which may be regarded as a uniformly distributed load.

Thus $pb =$ uniformly distributed load (in tons) on cantilevers per lineal foot of wall

and $pbs =$ uniform load in tons on each beam.

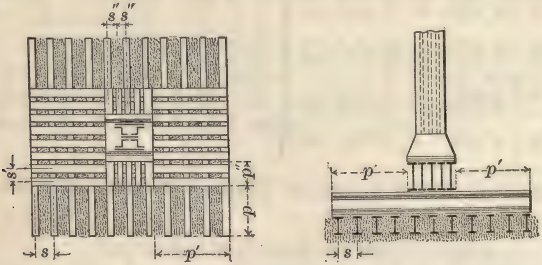
The table on page 25 gives the safe lengths p for the various sizes and weights of beams for $s = 1$ ft. and b ranging from 1 to 5 tons per square foot. For other values of s, say 15 in. or $1\frac{1}{4}$ ft., the table may be used by simply considering b increased in the same ratio as s (see example below). As regards the weight of beams, it is advantageous to assign to s as great a value as is warranted by the other considerations which obtain.

Example.—The weight of a brick wall together with the load it must support is 40 tons per lineal foot. The width of the lowest footing-course of masonry is 6 ft. Allowing a pressure of 2 tons per square foot on the foundation, what size and length of I beams 18 in. centre to centre will be required?

Answer.—$L = 40$, $b = 2$, $w = 6$, $s = 1\frac{1}{2}$.

Therefore $W = 40 \div 2 = 20$ ft., the required length of beams. The projection $p = \frac{1}{2}$ (20-6) $= 7$ ft.

In order to apply the table calculated (for $s = 1$ ft.) we must consider b increased in the same ratio as s, i.e., $b = 2 \times 1\frac{1}{2} = 3$ tons.



In the column for 3 tons we find the length 7 ft. to agree with 20-in. I beams 65.0 lbs. per foot.

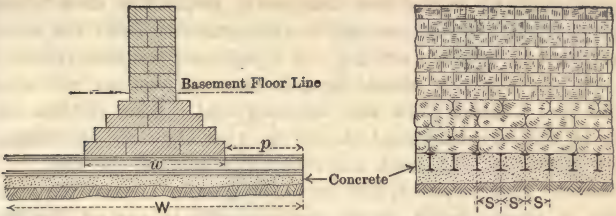


TABLE GIVING SAFE LENGTHS OF PROJECTIONS p IN FEET (SEE ILLUSTRATION) FOR $s=1$ FOOT AND VALUES OF b RANGING FROM 1 TO 5 TONS.

Depth of Beam in Inches.	Weight per Foot.	b (Tons per Square Foot).										
		1	$1\frac{1}{4}$	$1\frac{1}{2}$	2	$2\frac{1}{4}$	$2\frac{1}{2}$	3	$3\frac{1}{2}$	4	$4\frac{1}{2}$	5
24	80.00	15.231	13.61	12.43	10.77	10.16	9.63	8.79	8.14	7.62	7.18	6.81
20	80.00	13.983	12.50	11.41	9.89	9.32	8.84	8.07	7.47	6.99	6.59	6.25
20	65.00	12.488	11.16	10.20	8.82	8.33	7.90	7.21	6.68	6.24	5.89	5.58
18	55.00	10.857	9.71	8.86	7.68	7.23	6.87	6.27	5.80	5.43	5.12	4.86
15	80.00	11.892	10.63	9.71	8.41	7.93	7.52	6.86	6.36	5.95	5.61	5.32
15	60.00	10.405	9.30	8.49	7.36	6.94	6.58	6.01	5.56	5.20	4.90	4.65
15	42.00	8.861	7.92	7.23	6.27	5.91	5.60	5.12	4.74	4.43	4.18	3.96
12	40.00	7.730	6.91	6.31	5.47	5.15	4.89	4.46	4.13	3.87	3.64	3.46
12	31.50	6.925	6.19	5.65	4.90	4.55	4.38	4.00	3.70	3.46	3.26	3.10
10	25.00	5.706	5.10	4.66	4.03	3.80	3.61	3.29	3.05	2.85	2.69	2.55
9	21.00	5.016	4.48	4.09	3.55	3.34	3.17	2.90	2.68	2.51	2.36	2.24
8	18.00	4.354	3.89	3.55	3.08	2.90	2.75	2.51	2.33	2.18	2.05	1.95
7	15.00	3.715	3.32	3.03	2.63	2.48	2.35	2.14	1.98	1.86	1.75	1.66
6	12.25	3.112	2.78	2.54	2.20	2.07	1.97	1.80	1.66	1.56	1.47	1.39
5	9.75	2.539	2.27	2.07	1.80	1.69	1.61	1.47	1.36	1.27	1.20	1.14
4	7.50	1.994	1.78	1.63	1.41	1.33	1.26	1.15	1.07	1.00	0.94	0.89

The size of beam for any other pressure is found by multiplying the projection by the square root of the assumed pressure and finding the beam having a projection corresponding to this product under the one-ton column.

Footing-courses.—Footing-courses are usually made of concrete or large flat blocks of stone or granite. If of concrete they should not be less than 12 inches in thickness, but this thickness should be governed by the width or area covered, and where stepped up, the offset should not be more than one-half the height of the respective course; if not reinforced with steel beams they should not be loaded with more than 8000 pounds per square foot. If reinforced by beams the load may be increased to from 12,000 to 16,000 pounds. The same precaution should be taken with the beams as described under Spread Footings. When concrete is used for footings the

superintendent should see that wood forms are used where the earth is not firm enough to cut square to form the sides, and that all trenches are dug out square and bottoms trimmed level; the concrete should be put down in courses not more than 6 or 8 inches thick and rammed solid. After the footings are in the superintendent should see that they are thoroughly wet every day for a week and covered to keep off the sun.

STONE FOOTINGS.—Where stone or granite is used for footings, it should be of blocks large enough to extend the full width of the footing, and from 4 to 8 feet in length; where it is not possible to obtain stone large enough to extend through the footing they may be jointed under the centre of the wall and a second course of single stone put on top, as shown by Fig. 24.

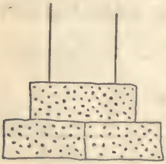


FIG. 24.

The stone should have uniform beds, and where two or more courses are used the offset should not be more than three-quarters of the height of the under course. The stone should be set in strong cement mortar and on a full bed under the entire stone; stone in footings should not be subject to a pressure of more than 10,000 to 14,000 pounds per square foot.

In setting stone footings the superintendent should see that each stone is squared off so they will fit close together, and no spalls used to fill up the joints; the top and bottom beds should be dressed off and set in a full bed of mortar and all vertical joints slushed full. Unless the superintendent is on the lookout the mason is liable in levelling the stone to raise it up and wedge it with a spall and then try to slush the mortar beneath the stone; this should not be allowed, but when a stone has to be raised any, have it lifted, a new bed of mortar spread, and the stone reset and beat down until it comes to a solid bearing.

BRICK FOOTING.—When brick is used for footings the bottom courses should be double, or composed of three separate courses, and the outside courses in a step footing should all be headers, so as to keep the joints back as far from the face of the footing as possible. The superintendent should see that only the hardest bricks are used, and that they are laid in the best of cement mortar, and that all joints are slushed full. In some cases where piers carrying a heavy weight rest on the footing-course it is advisable to turn inverted arches from pier to pier,

as shown by Fig. 25. The concrete should be put in and shaped to the desired circle and several concentric courses of brick built in as shown.

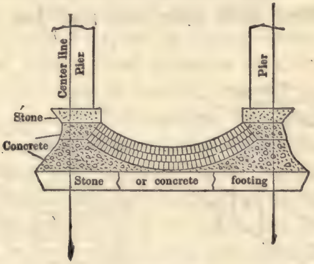


FIG. 25.

Foundation-walls.—STONE.—Where stone is to be used for foundation-walls, it should come from a quarry that is well known and the stone such as has been tested by use. It should be a hard compact stone and one which can be quarried in large blocks; care should be exercised at the quarry to get out the stone in such sizes as is desired, and so that they will lay in the wall on their natural bed.

The specifications usually mention how close headers or bond stone are to be built, as: "One-sixth of the face surface of the wall shall consist of bond stone or headers extending through the wall."

For ordinary structures the walls are usually built as shown in Fig. 26, 1, 1, 1 representing the bond stone and 2, 2, 2 the headers at a jamb or opening.

For large and more important structures the stone should be large blocks and laid in courses as shown by Fig. 27; every alternate course should have headers as indicated by 1, 1, 1. The superintendent should pay close attention to the mason when at work and see that every stone is set in a full bed of mortar and all joints slushed full. A mason usually if let alone will set a stone down and wedge up under with spalls until the stone will not rock, then plaster some mortar around it and call it set. The superintendent must also watch the filling of any cavities between the stone and see that they are filled solid with small stone and mortar. Wherever pipes of any kind are to pass through the wall, openings of a suita-

ble size should be left so that there will be no weight of the wall resting on the pipes. Or a better method is to build pipe-sleeves in the wall large enough for the pipe to pass through.

FILLING.—The filling around the outside of the wall should never be permitted until after the wall has been built long

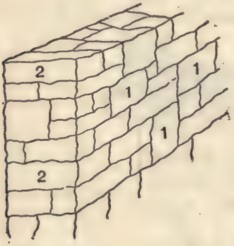


FIG. 26.

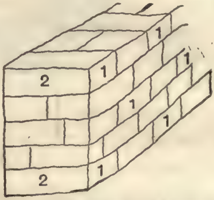


FIG. 27.

enough for the mortar to harden, and the beams of the first floor put in place, so as to prevent the walls from being shoved in by the pressure of the earth. In filling the superintendent should see that nothing but clean solid material is used and put in in layers of about 12 inches and well rammed, or, as is better, "puddled" into place. Where there is danger of dampness the walls should be plastered as shown and described on page 5.

Stonework.—NATURAL STONES.—The duty of selecting the stone or any other building material usually devolves upon the architect or engineer who prepares the plans and specifications, and unless the stone comes from a well-known and tried quarry it should be given thorough tests, and for a structure of any importance a new stone, or one that has not been in use any length of time, should not be used, unless by making severe tests the architect or the superintendent is convinced it will stand, as to strength and weathering qualities. Time and exposure to the elements are the best test for any stone.

Granite and Allied Rocks.—Granite as a rule can be quarried in any size that can be handled, and when coming from an old quarry the durability of it will be known, but if from a new quarry it should be tested. The usual color of granite is a light or dark gray, although different shades, from light

pink to red, are found in different localities. The color of granite is generally determined by the color of the feldspar in it, or by the color of the mica which it contains.

Granite, being so hard to work and thus being more expensive than the softer rocks, is not used much except for the more expensive buildings, or in places where other stones are not desired and where great strength must be had.

Gneiss, which is a sort of bastard granite, has much the same composition as granite, but lays in the quarry in layers. It can be easily quarried and makes good footings or foundations and street curbs or crossings. The superintendent should make himself familiar enough with gneiss to tell it from granite, for some contractors will try to substitute it for granite.

During the construction of the dry-dock at the Charleston, S. C., navy yard the United States Navy Department rejected the stone sent for constructing the dock, on account of it being gneiss, when granite was specified.

Syenite.—This is a rock which resembles granite, but contains no quartz. It is very little used, the principal quarries being in Arkansas.

Trap and Basalt.—These rocks are very hard, compact, and tough and are used for road-making and street-paving.

The principal granite quarries are found in the New England States. The table on page 30 will show the location of some of the best known quarries and buildings in which the granite was used.

A good granite should last from 75 to 200 years without showing any signs of discoloration or disintegration.

When using granite, the superintendent should examine all stones as they are brought to the building, both as to quality and workmanship, as granite is usually cut at the quarry and will come to the job ready to set. He should watch to see that there is not too much contrast in the color of the stones, as in some granites there is quite a difference in the color of the stone coming from different parts of the same quarry. He may find "knots" which are lumps of a different color from the body of the stone. They are usually much lighter or darker, and when found the stone should be rejected. "Sap," which is a stain in the stone, and "shakes," which are cracks or seams, should be sufficient cause to reject any stone containing them.

The table on page 31 shows the load per square inch at which

Location of Quarry.	Building Used in.	Color.
Concord, N. H.	National Library, Washington, D.C.	Light gray
" "	N. H. State House	Light gray
Hallowell, Maine	State Capitol, Albany, N. Y.	Light gray
Quincy, Mass.	King's Chapel, Boston	Dark gray
" "	U. S. Court-house, Boston	Dark gray
" "	Masonic Temple	Dark gray
" "	Stairway, pilasters, etc., City Hall, Philadelphia, Pa.	Dark gray
Dedham, Mass.	Trinity Church, Boston	Pink
Vinalhaven, Mass.	Masonic Tempie, Philadelphia	Gray
Red Beach, Maine		Red & pink
Jonesboro, Maine		Red & pink
Dix Island, Maine	New York Post-office	
Cape Ann, Mass	Post-office, Boston	
Milford, Mass.	City Hall, New York	
North Conway, N. H.	Union Depot, Portland, Me.	Red & green
Lynn, Conn.	Chaney Memorial Church, Newport, R. I.	Deep red
Grindstone, N. Y.	Columns, State Capitol, Albany, N. Y.	
Westerly, R. I.		Light gray and pink
Richmond, Va.	State, War, and Navy Department buildings, Washington, D. C.	Gray
Georgia		Light and dark gray
Graniteville, Mo.		Red mottl'd with gray
St. Cloud, Minn.		Gray & red
Gunnison, Colo.	Colorado State House	Blue gray
Little Cottonwood Canyon	Utah Mormon Temple, Salt Lake City.	

various granites fail by crushing. It is not safe to use more than one-tenth for a working strength.

The New York Building Code gives the working strength of granite at 1000 to 2400 pounds per square inch, according to test.

The table on page 32 gives the analysis of granites from some of the most prominent quarries.

The table on page 33, prepared by the United States Geological Survey, shows the amount of granite produced in the United States and for what purpose used during the year 1901.

Sandstone.—Sandstones are stratified rocks composed of small grains of crystal quartz which are cemented together by argillaceous, calcareous, silicious, or ferruginous material, and from this material often derive the name of argillaceous, calcareous, etc., stones. The strength, durability, and color of the stone rests with this cementing material to a great extent.

STRENGTH AND WEIGHT OF VARIOUS GRANITES.

State.	Location.	Strength per Sq. Inch.	Weight per Sq. Foot.
Arkansas	Pulaski Co. (gray granite)	14,000	...
"	Fourth Mountain (syenite)	30,740	167
California	Rocklin	30,740	167
Colorado	Gunnison	12,976	165
"	Platte Canyon (red)	14,585	168
Connecticut	Middleton	21,460	...
"	Waterford	23,510	...
"	Meriden (trap rock)	34,920	...
"	Kirkland rocks	35,000	166
"	Lord's Island	24,000	...
"	Mystic River	22,250	164
"	New Haven	9,750	...
"	Millstown Point	16,187	169
"	Milford	22,600	...
"	New London	12,500	166
Georgia	Lithonia	25,630	...
Maine	Hurricane Isle	19,538	167
"	Jonesboro (red)	24,507	...
"	Waldoboro (white)	23,111	...
"	North Jay (red)	22,367	...
"	Dix Island	15,000	166
"	Fox Island (blue)	15,000	164
"	Sharkey's Quarry	22,125	170
"	Vinalhaven (gray)	17,000	...
Massachusetts	Cape Ann	20,296	164
"	Milford (pink)	30,888	...
"	Milford (Norcross Bros.)	20,883	...
"	Quincy (dark)	17,750	166
"	Quincy (light)	14,750	166
"	Fall River (gray)	15,937	...
Michigan	Huron Island	18,125	164
Missouri	Graniteville	24,181	...
Minnesota	East St. Cloud	28,000	168
"	Duluth (dark)	17,631	175
"	Duluth (light)	19,000	...
New Hampshire	Troy	17,950	168
"	Keene (blue gray)	12,000	166
New York	Goshen	23,500	...
"	Staten Island (blue)	22,250	178
"	Tarrytown	18,250	162
New Jersey	Scotch Plains (trap rock)	17,950	...
"	Passaic Co. (gray)	24,040	...
"	Jersey City	20,750	189
Rhode Island	Westerly (gray)	17,500	165
South Carolina	Carlisle	29,150	...
Texas	Burnet Co.	11,891	176
Vermont	Barre (dark)	19,975	...
"	Barre (light)	17,856	...
Virginia	Peters	25,100	...
"	Richmond	25,520	...

The argillaceous is a soft stone cemented with a clayey matter and disintegrates very easily.

The calcareous stone is cemented with carbonate of lime. This stone is soft and easy to work, but does not weather well.

In ferruginous stone the cementing material is composed of iron oxides, which cause the red or brown color. This stone is harder than the two last mentioned; does not work so easy, but stands the weather well.

CHEMICAL ANALYSIS OF GRANITES FROM VARIOUS QUARRIES.

State.	Location.	Quarry.	Silica.	Oxide of Alumina.	Oxide of Magnesia.	Oxide of Sodium	Oxide of Potassium.	Oxide of Iron.	Oxide of Calcium.
California	Exeter	Rocky Point Granite Works.	75.35	13.69	.06	1.14	2.85	3.94	2.97
Connecticut	Waterford	Hurricane Isle Granite Co.	68.11	14.28	.68	6.57	5.46	....	1.86
"	Meriden	(Trap rock).	52.37	15.06	5.38	4.04	....	....	7.33
Delaware.	Rockford.	Brandywine G't Co. (gneiss).	67.98	16.14	.53	4.32	.45	....	5.89
Maine.	Waldoboro.	Booth Bros	73.48	15.26	.09	3.12	5.66	....	....
"	North Jay.	Maine and N. H. Granite Co.	71.54	14.24	....	3.39	4.73	....	.98
"	Blue Hill	Chase Granite Co.	73.02	16.22	....	3.60	3.42	....	.94
"	" "	Blue Hill Granite Co.	74.64	14.90	....	.41	6.88	....	.39
Maryland.	Point Deposit	M'Clenahan Bros.	73.69	12.89	.49	2.81	1.48	....	3.73
Minnesota.	East St. Cloud	....	65.12	16.96	....	5.25	....	4.69	4.77
Massachusetts.	Cape Ann.	Rockport Granite Co.	81.05	14.70	....	....	....	....	1.10
"	Milford.	Shea Pink Granite Co.	76.95	11.15	....	5.60	5.03	....	....
"	"	Norcross Bros.	76.07	12.67	.10	3.37	4.71	....	.85
"	Monson.	(Trap rock).	52.59	23.42	.28	....	....	....	9.05
"	"	Light granite.	73.47	15.07	....	5.97	....	1.15	4.48
"	"	Dark granite.	69.35	18.23	....	3.78	....	2	5.94
Nevada.	Reno.	Jno. Barret.	58.67	14.89	1.79	7.68	2.69	....	5.68
N. Hampshire.	Red Stone.	N. H. Granite Co. (red).	71.44	14.72	.96	7.66	.89	....	....
"	" "	" " " (green)	70.42	14.64	1.20	7.80	.71	....	....
"	Troy.	Troy Granite Co.	73.15	17.04	.30	2.05	5.74	....	.81
"	Mason.	Mason Granite Co	72.47	16.17	.14	3.43	4.83	....	1.65
New Jersey	Little Falls.	Francesco Bros. (trap).	50.81	13.25	6.97	.76	1.71	....	10.96
New York.	Stormy P't.	Daniel Donovan	63.19	10.50	1.43	1.91	4.01	....	6.12
Pennsylvania.	Birdsboro.	John T. Dyer Co.	46.87	13.36	4.35	4.64	2.01	....	14.70
Vermont.	Barre.	Wells, Lamson & Co.	69.56	15.38	....	5.38	4.31	....	1.76
Virginia	Petersburg	Petersburg Granite Co.	64.12	20.91	.66	4.57	4.82	2.96	1.98
"	Richmond	P. Copeland.	60.65	16.87	2.39	2.18	3.80	....	1.91
Wisconsin.	Waushara Co.	Milwaukee Monument Co.	76.62	13.02	.05	2.24	6.38	....	.51
"	Berlin.	E. J. Nelson.	73.65	11.19	.51	3.74	1.86	....	2.78

PRODUCTION AND USE OF GRANITE IN U. S. DURING THE YEAR 1901.

State.	Sold in the Rough.			Dressed for Building.	Dressed for Monumental Work.	Made into Paving Blocks.
	Building.	Monumental.	Other.			
Arkansas						$2,627
California	$24,057	$38,755	$6,815	$358,832	$72,257	46,300
Colorado	45,650	7,562		60,835	1,787	5,750
Connecticut	108,959	26,267	24,384	94,611	70,894	29,533
Delaware	9,069		2,678	1,750	400	32,191
Georgia	54,321	22,315	2,725	57,207	14,526	328,087
Idaho	100	5,000				
Indian Territory, Kansas	2,340			7,800		
Maine	407,418	24,475	27,447	1,501,797	76,276	401,189
Maryland	181,608	20,180	1,500	188,568	7,800	51,637
Massachusetts	333,047	236,327	118,567	455,535	236,273	364,721
Michigan						
Minnesota	13,215	42,197	1,550	55,017	96,902	20,002
Missouri	550	17,406	2,095			40,651
Montana, Nevada				15,600	3,500	
New Hampshire	156,832	52,231	9,797	363,957	171,239	112,581
New Jersey	60,905	2,515		19,888		87,933
New York	24,312	1,325	6,150	97,350	6,283	33,025
North Carolina	27,464	4,105	2,212	68,975	6,813	10,862
Oregon	3,748	250	1,590	3,900	1,116	
Pennsylvania	63,568	1,050	4,538	18,916	227	15,712
Rhode Island	9,722	92,974	110	160,190	198,831	27,666
South Carolina	56,831	23,433	5,730	165,594	12,789	8,276
South Dakota	25,106		2,159	1,650		52,089
Texas	2,652	11,521		243	10,400	
Utah	2,288	3,300				
Vermont	208,825	534,755	101,779	16,343	354,563	16,304
Virginia	40,763	8,300	230	45,737	52,404	17,253
Washington	9,100	2,250		3,000		3,360
Wisconsin	3,575	79,175	28,015	17,999	62,277	113,682
Wyoming	2,810					
Total	1,878,835	1,257,668	350,071	3,781,294	1,457,557	1,821,431

The silicious stone, being cemented with silica, which has about the same composition as the grains of sand of which the stone is composed, makes a stone very hard and one which will weather well. The color of the stone is usually due to the amount of iron contained in it. The more iron the darker the stone. The iron oxides in the stone do no harm, but iron pyrites or sulphate of iron in light sandstones is sure to stain or rust the stone.

Sandstone being of a sedimentary formation, it is usually found in the quarry in layers, or there is a well-defined grain to the stone in the direction of its natural bed, which causes it to split readily. In working the stone, the superintendent should see that the stone is cut so it will set in the wall as it lay in the quarry, or on its natural bed. If it is set on edge it is sure to scale off as the frost and moisture penetrates it.

As nearly all the sandstones are very soft when first quarried

the superintendent should see that too much weight is not put on them until they have had time to season or harden after being taken from the quarry.

The defects usually found in sandstones are "drys" (seams which are not cemented together), and holes or cavities filled with sand or clay or uncemented material.

Sandstones are of great variety and color, and are found in all parts of the country, the different colors coming from different localities. Dark brown is found near Portland, Conn.; Hummelstown, Pa.; Marquette, Mich.; West Virginia; North Carolina; Indiana; Arizona, and Colorado. Red is found at East Longmeadow, Mass.; Potsdam, N. Y.; Fon du Lac, Minn.; Manitou, Col.; Glenrock, Wyoming, and Portage Entry, Mich. (Lake Superior sandstone). Perhaps the most extensively used sandstone comes from Ohio, near Cleveland, and is of a light buff or gray color.

Missouri has several quarries of a gray sandstone which has been used extensively in St. Louis and Kansas City.

The following table shows some of the principal quarries and buildings in which the stone has been used.

State.	Location of Quarry.	Building Used in.	Color of Stone.
Conn..	Portland.	Technology Building, Boston.	Brown
"	"	Astor Library, New York City.	Brown
"	"	Music Hall, Buffalo, N. Y.	Brown
"	"	Union League Club B'ld'g. Phila.	Brown
"	"	Savings Bank of Baltimore.	Brown
"	"	Residence of W. H. Vanderbilt, New York.	Brown
Colo. .	Fort Collins.	Grace Methodist Church, Denver	Dark red
"	"	Union Pacific Depot, Cheyenne, Wyoming.	Dark red
Mass. .	Longmeadow.	Union League Club, Chicago.	Red
"	"	Trimmings Trinity C'ch, Boston..	Red
Mich. .	Portage Entry (Lake Superior)	New Waldorf-Astoria Hotel, N.Y.	Red
"	Do. do.	U. S. Post-office, Rockford, Ill	Red
"	Marquette	Court House, Muskegon, Mich	Brown
Minn..	Kettle River	Library Bldg., Univ. of Illinois.	Cream
"	Fond du Lac.	Presbyterian Church, Minneapolis, Minn.	Reddish brown
N. Y. .	Potsdam.	Parliament B'ld'gs, Ottawa, Ont.	Red
"	"	Columbia College, New York City.	Red
"	Medina.	U. S. Government Building, Rochester, N. Y.	Pink
Ohio. .	Amherst	Palmer House, Chicago.	Buff
"	"	State Capitol, Lansing, Mich	Buff
"	"	State Historical Library, Minneapolis, Minn.	Buff
"	"	Wood Co., Ohio, Court House.	Gray
"	Berea.	U. S. Post-office, Minneapolis, Minn.	Blue-gray
Pa. . . .	Hummelstown	U. S. Marine Barracks, League Island	Brown

The following table shows the value of the sandstone production in the United States from 1897 to 1901, inclusive, by States.

VALUE OF SANDSTONE PRODUCTION IN THE UNITED STATES FROM 1897 TO 1901, INCLUSIVE, BY STATES.

State.	1897.	1898.	1899.	1900.	1901.
Alabama	$3,000	$27,882	$71,675	$7,132	$8,680
Arizona	15,000	57,444	4,168	64,000	202,500
Arkansas	3,161	24,825	73,616	104,923	62,825
California	4,035	358,908	261,193	200,090	301,028
Colorado	60,847	89,637	129,815	119,658	237,331
Connecticut	364,604	215,733	271,623	192,593	146,814
Georgia	....	....	....	600	....
Idaho	....	....	....	438	20,843
Illinois	14,250	13,758	16,133	19,141	12,884
Indiana	35,561	45,342	35,636	45,063	34,959
Iowa	14,771	7,102	24,348	19,063	14,341
Kansas	20,953	19,528	49,629	55,173	49,901
Kentucky	40,000	72,525	119,982	56,178	108,259
Louisiana	8,000	200,500	[1] 226,503	[2] 118,192	....
Maryland	....	13,646	24,426	6,655	4,546
Massachusetts	194,684	91,287	131,877	153,427	247,310
Michigan	171,127	222,376	320,192	238,650	290,578
Minnesota	158,057	175,810	294,615	267,000	246,685
Missouri	57,583	48,795	57,662	53,401	42,170
Montana	25,644	3,682	26,160	59,630	60,719
Nebraska	....	....	....	....	515
New Jersey	190,976	257,217	147,768	198,234	244,512
New Mexico	....	3,500	1,829	2,500	....
New York	544,514	566,133	[3] 1,218,053	[3] 1,467,496	[3] 1,331,327
N. Carolina	11,500	9,100	10,300	27,210	11,682
Ohio	1,600,058	1,494,746	1,775,642	2,233,596	2,576,723
Oregon	....	7,864	4,153	5,450	531
Pennsylvania	380,813	478,451	[3] 717,053	[3] 1,050,248	[3] 2,063,082
South Dakota	....	9,000	18,325	12,675	17,647
Tennessee	....	....	....	11,300	10,342
Texas	30,030	77,190	35,738	37,038	111,568
Utah	7,907	15,752	29,091	66,733	38,919
Virginia	....	....	8,000	6,000	5,303
Washington	16,187	15,575	58,395	68,133	89,174
West Virginia	47,288	14,381	33,860	72,438	106,710
Wisconsin	33,620	80,341	132,901	81,571	90,425
Wyoming	11,275	6,382	32,583	27,671	54,145
Totals	4,065,445	4,724,412	6,362,944	7,149,300	8,844,978

[1] Includes small amounts for Idaho and Nevada.

[2] Includes Mississippi.

[3] Includes bluestone.

The following table gives the crushing strength per square inch and weight per cubic foot of sandstones found in various parts of the country.

The working strength of any stone should not be more than one-tenth of its crushing strength. The New York Building Code gives the working strength of sandstones at 400 to 1600 pounds per square inch, according to test.

STRENGTH AND WEIGHT OF SANDSTONES.

State.	Location.	Color.	Strength per Sq. Inch.	Weight per Sq. Foot.
Arizona	Flagstaff	Chocolate	5,857	142
California	Colusa		8,880	...
Colorado	St. Vrains	Red	11,500	149
"	Fort Collins	Gray	11,707	140
"	Manitou	Red	11,000	140
Connecticut	Portland		10,871	148
"	Middletown	Brown	6,950	...
"	Cromwell		16,890	156
Indiana	Riverside	Gray	6,000	...
"	"	Blue	6,090	...
Iowa	La Grande		6,805	...
Kansas	Valley Falls		7,500	152
Kentucky	Langford		15,160	...
Massachusetts	East Longmeadow	Red	11,595	154
Missouri	Warrensburg	Blue-gray	9,687	149
Minnesota	Kasota	Pink	10,700	164
"	Kettle River	Pinkish buff	17,000	139
"	Frontenac	Buff	6,250	145
Michigan	Redrock		6,019	...
"	Portage Entry (Lake Superior)	Red	6,776	126
"	Marquette		7,450	158
New York	Potsdam	Red	18,401	162
" "	Medina	Pink	17,250	150
" "	Oxford	Blue	12,677	...
" "	Warsaw	Blue	19,968	167
" "	Albion	Brown	13,500	157
" "	Little Falls	Brown	9,850	...
" "	Haverstraw	Red	4,350	133
New Jersey	Belleville	Gray	11,700	147
" "	"	Brown	13,310	148
North Carolina	Carthage		12,750	...
Ohio	Seneca	Reddish brown	5,000	134
"	Lancaster		5,950	...
"	Amherst	Buff	9,450	133
"	Berea	Dark drab	9,510	134
"	Cleveland	Olive-green	6,800	140
"	Vermillion	Drab	8,850	135
"	Massilon	Yellow-drab	8,750	...
Pennsylvania	Hummelstown	Brown	13,097	...
"	Laurel Run		22,250	166
"	White Haven		29,250	...
South Dakota	Hot Springs		6,914	...
" "	Rapid City	Gray	11,452	...
" "	" "	Red	6,116	...
Washington	Chuckanut		10,276	...
Wisconsin	Fon du Lac	Purple	6,237	138
Wyoming	Rawlins		10,883	...

The table on the page opposite gives the chemical analyses of some of the principal sandstones.

Limestone.—The varieties of limestones used for building purposes are: Oolitic, limestones which are composed of small round grains that have been cemented together with lime to form a solid rock; magnesian limestones, which contain 10 per cent or more of carbonate of magnesia; dolomite, limestones which are an aggregation of the mineral dolomite; the latter is

CHEMICAL ANALYSIS OF VARIOUS SANDSTONES.

State.	Location.	Quarry.	Silica.	Oxide of Alumina.	Oxide of Magnesia.	Oxide of Sodium.	Carbon.	Oxide of Potassium.	Ferric Oxide	Oxide of Calcium.	Water and Loss.
Arizona.	Flagstaff.	Arizona Sandstone Co.	79.19	1.30	.23		5.77		2.45	7.76	.32
California.	Colusa.	Colusa Stone Co.	85.99	4.82	.76				4.49	1.87	.69
Connecticut.	Cromwell.	N. E. Brown Stone Co.	70.84	13.15		5.43	1.01	3.30	2.48	3.09	
"	Portland.	(Brown stone).	69.94	13.15					2.48	3.09	1.01
Indiana.	Riverside.	Guyer & Burchby.	93.16	1.60					2.64	.13	
"	St. Anthony.	J. B. Lynn.	88.41	.63			10		8.40	.13	
"	Williamsport.	Williamsport Stone Co.	98.57	.05			.02		.65	.02	
Kansas.	Valley Falls.	J. M'Ginty.	94.35	2.35	1.01					1.14	
Kentucky.	Rock Castle.	Rock Castle Blue Stone Co.	91.07	4.92						1.18	2.36
Maryland.	Frostburg.	B. Randolph.	99.40	.47					.27	.10	
Michigan.	Lake Superior	Portage Entry Quarries Co.	85.60	8.32	.18	.53		2.91	.28	.55	.99
Massachusetts.	E. L'gmeadow	Norcross Bros.	81.38	9.44	.28				3.54	.76	
"	Worcester.		88.89	5.95					1.79	.27	1.83
Minnesota.	Kettle River	Minnesota Sandstone Co.	98.69	1.06	.01	.17				.42	
"	Fon du Lac		78.24	10.88					3.83	.95	
New Jersey	Avondale.	Passaic Quarry Co	82.05	5.27	.76	20	4.40	.60	2.71	3.35	.71
New York	Oxford.	F. G. Clark Co	77.56	10.65	1.22	.90		2.15	4.59	.34	1.93
" "	Stoneco.	Hudson River Stone Co	63.24	19.52							
" "	Rock Glenn.	Warsaw Blue Stone Co.	76.50	14.75	1.29		2.72		6.35	3.80	2.00
N. Carolina	Carthage.	A. H. M'Neal.	79.63	7.16	2.63			4.66	4.16	.92	
Ohio.	Amherst		97.00		.97				2.30	1.86	.20
"	Berea.		96.00						1.68	1.15	.21
"	Massilon.	Chippewa Stone Co.	97.36	2.28	.08					.05	
"	Lancaster.	F. C. Neeb.	97.76	.73					.51	.12	.51
"	Euclid.		95.00	2.50					1.00		
"	Grafton.		87.66	1.72					3.52	.17	2.03
Oregon.	Chitwood.	Victor Sandstone Co.	72.45	12.60					10.80	4.10	1.50
"	Forest Grove.	Forest Grove Stone Co.	55.21	17.87					14.75	2.19	
Pennsylvania.	Hummelsto'n	Hum'town Bluestone Co. (blue)	90.34	4.35	.17	.19		1.30	1.09	.95	.61
"	"	Do. do. do. (brown)	88.96	4.74	.44	.24		1.31	2.19	.86	.87
"	Swarta.	Swarta Stone Co.	91.52	3.80	.22			1.20	2.02	.50	1
"	Laurel Run.	Laurel Run Stone Co.	94.00		1.00				1.98	1.10	.92
"	White Haven	Pennsylvania Quarry Co.	90.36	2.17					1.15	2.00	1
"	Lathrop.	Frank Carlucci	91.40	6.64					.16		3.28
Utah.	Jennings Spur	Kyune Gray Stone Co.	83.64	.46	.70				1.96	8.50	.22
Wisconsin.	Ashland.	Prentice Stone Co.	91.40	3.53		.14		2.36	2.00	.25	.05

usually of a light color and is generally much harder and heavier than the other limestones.

The most extensive quarries of limestone are near Bedford, Ind., from where stone is shipped to nearly all parts of the country. At Carthage, Mo., are several quarries of limestone of a coarse crystalline nature and which takes a good polish; this stone is found in layers, and the largest clear stone which

PRODUCTION OF LIMESTONE IN THE UNITED STATES IN 1900 BY STATES AND USES.

State or Territory.	Building Purposes.	Paving and Road-making.	Riprap.	Made into Lime.	Stone Sold to Lime-burners.	Flux.	Other Purposes.	Total.
Ala.	$83,380	....	$14,697	$139,090	......	$296,241	$200	$533,608
Ariz.	165	....	......	....	......	....	......	165
Ark.	5,994	$665	......	64,038	$200	....	510	71,407
Cal.	1,937	87,128	325	297,810	316	1,080	18,893	407,489
Colo.	....	1,274	......	96,055	75	62,413	770	160,587
Conn.	....	25	......	145,490	......	2,545	......	148,060
Fla.	....	6,988	97,023	24,370	......	....	......	128,381
Ga.	1,200	10,735	......	39,492	2,000	1,024	......	54,451
Idaho	....	9,000	......	25,587	......	....	......	34,587
Ill.	499,739	859,602	96,900	246,575	......	114,849	63,486	1,881,151
Ind.	1,639,985	239,913	11,451	227,343	......	168,692	57,434	2,344,818
Iowa.	248,883	153,929	58,493	110,589	580	....	13,936	586,410
Kan.	203,304	113,952	7,586	3,192	1,125	....	10,307	339,466
Ken.	21,623	115,730	12,500	8,393	......	17,728	2,278	178,252
Maine	....	....	......	629,545	4,218	883	56,666	691,312
Md.	11,385	14,343	524	281,717	3,726	3,867	1,645	317,207
Mass.	8,175	....	......	199,645	......	1,539	......	209,359
Mich.	32,362	105,266	799	94,789	65,000	3,200	124,220	425,636
Minn.	323,688	27,778	32,912	42,480	400	300	13,996	441,554
Mo.	362,344	235,489	57,023	398,010	......	8,288	18,189	1,079,343
Mon.	3,000	2,093	......	19,000	......	117,000	......	141,093
Neb.	39,556	31,442	10,488	590	7,088	13,125	5,016	107,305
N. J.	6,955	1,299	1,000	105,902	286	54,564	......	170,006
N. Y.	244,738	484,902	21,668	676,324	40,838	71,408	190,284	1,730,162
Ohio.	217,399	466,819	47,530	661,869	14,939	422,407	138,424	1,969,387
Okla.	2,672	22,914	......	....	......	....	......	25,586
Ore.	....	....	......	10,525	375	....	......	10,900
Penn.	128,997	684,983	660	910,903	21,799	1,949,859	103,117	3,800,318
R. I.	....	....	......	16,715	......	113	......	16,828
S. Car[1]	....	500	......	36,320	......	1,595	......	38,415
S. Dak	300	....	......	14,380	......	33,082	......	47,762
Tenn.	22,800	26,490	396	128,035	120	60,564	100	238,505
Texas.	15,681	9,821	250	79,659	......	18,942	375	124,728
Utah.	11,979	....	......	770	......	....	......	12,749
Vt.	193	32	......	187,075	......	....	800	188,100
Va.	5,070	8,721	......	151,687	......	237,840	......	403,318
Wash.	....	240	......	239,022	......	6,643	3,258	249,163
W. Va.	9,391	40	......	36,677	5,851	1,742	......	53,701
Wis.	177,386	231,356	110,263	445,193	3,630	15,861	5,996	989,685
Wy.	425	....	......	2,640	......	....	......	3,065
Totals	4,330,706	3,953,469	582,488	6,797,496	172,566	3,687,394	829,900	20,354,019

[1] Includes North Carolina.

can be got out is 20 inches in thickness. The United States Post-office at Joplin, Mo., was built of this stone, which gave very good satisfaction. The stone is very dense, heavy, and does not absorb moisture. At Lockport, N. Y., is quarried a gray limestone which is used much in the east for trimmings. Ohio, New York, Pennsylvania, Illinois, Minnesota, and Wisconsin also produce much limestone for building purposes.

All limestones should be set with non-staining mortar made of non-staining cement, as other cements will generally stain right through the stone or stain dark around the joint.

In some limestones are found pieces of flint, and when these are of any size and appear on an exposed surface of the stone, the stone should be rejected. The other defects of limestone are about the same as those found in sandstones and require the same inspection.

The table on page 38 shows the value of the limestone production in 1900 by States and uses.

The following table gives the crushing strength per square inch and the weight per cubic foot of limestones from various parts of the country.

State.	Location.	Strength per Sq. Inch.	Weight per Cu. Foot.	State.	Location.	Strength per Sq. Inch.	Weight per Cu. Foot.
Ark. . .	Johnston.	15,500	. . . .	Mich.	Lime Island	18,000	. . . .
Ill. . . .	Kankakee.	13,544	165	Mo. . .	Carthage (white)	14,950	185
" . . .	Joliet (white) . .	14,775	160	"	Cooper Co. (dark drab).	6 650	141
" . . .	Quincy.	9,687	160				
" . . .	Grafton.	17,000	. . . .	N. Y.	Glens Falls.	11,475	168
Ind. . .	Bedford.	6,000	154	"	Lake Champlain	25,000	171
" . . .	Bloomington. . .	4,100	. . . .	"	North River. . . .	11,475	169
" . . .	Salem.	9,000	156	"	Canajoharie. . . .	20,700	168
" . . .	Stinsville	5,600	. . . .	"	Erie Co. (blue). .	12,250	165
Iowa. .	La Grande.	10,825	. . . .	"	Kingston	13,900	168
" . .	Stone City.	11,250	136	"	Garrison.	18,500	165
Kan. .	Marion.	12,364	168	Ohio.	Marbleh'd (w'e).	12,600	150
Ky. . .	Warren Co.	6,795	. . . .	Wis. . .	Sturgeon Bay (blue).	21,500	174
" . . .	Bardst'n (da'k).	16,250	168				
Minn. .	Winona.	16,250	160	" . .	Waukesha	8,880	. . . .
"	Stillwater.	15,000	172	Pa. . . .	Avondale (gray)	18,000	. . . .
"	Redwing.	23,000	162	" . . .	" (light)	12,112	. . . .
				" . . .	Conshohocken.	15,000	. . . .

The following table gives the chemical analysis of the limestone from some of the various quarries.

CHEMICAL ANALYSIS OF VARIOUS LIMESTONES.

State.	Location.	Quarry.	Carbonate of Calcium.	Carbonate of Magnesia.	Ox. Iron & Alumina.	Silica.	Oxide of Calcium.
Ill. . . .	Quincy.	F. W. Menke Stone Co. .	92.77	6.75	.27	15.90	. . . .
" . . .	Lemont.	. . . .	45.80	. . . .	9.30	15.90	. . . .
" . . .	Joliet.	. . . .	. . . .	. . . .	. . . .	. . . .	. . . .
Ind. . .	Bedford	Bedford Quar. Co.	98.20	.39	.39	.63	. . . .
" . .	"	" " " (blue)	97.26	.37	.49	1.69	. . . .
" . .	Spencer.	. . . .	96.80	.11	.91	.70	. . . .
" . .	Clear Creek. . . .	Acme Stone Co.	97.37	.78	.13	.84	.10
" . .	Peru.	J. N. Hurtz	52.90	38.94	1.25	4.05	. . . .
Iowa. .	Monmouth. . . .	L. B. Stewart Co.	57.54	41.51	. . . .	.42	. . . .
Kan. .	Marion.	I. Kuhn & Co.	91.50	1.62	1.24	5.51	. . . .
Ky. . .	Warren Co. . . .	Caden Stone Co.	54.80	. . . .	.22	.76	. . . .
" . . .	Bowling Green	. . . .	95.31	1.12	.39	1.42	. . . .
Mich. .	Trenton	Sibly Quarry Co	98.53	.53	.06	.60	. . . .
Minn. .	Kasota.	. . . .	49.16	37.53	1.09	13.06	. . . .
"	Stillwater.	. . . .	50.22	37.39	.78	8.74	. . . .
"	Frontenac.	. . . .	54.78	42.53	.67	2.73	. . . .
Mo. . .	Carthage.	Myers Stone Co	98.57	.65	.21	.69	. . . .
N. Y. .	Cobbleskill	Cobbleskill Quarry Co. .	41.90	1.65	.97	4.31	51.05
"	Amsterdam. . .	. . . .	42.64	. . . .	1.08	3.82	52.46
Ohio. .	Cold Springs. . .	Casparis Stone Co	54.05	44.94	.23	.49	. . . .
" . .	Tiffin.	. . . .	. . . .	40.36	.10	1.61	57.44
" . .	Dayton.	. . . .	92.40	1.10	.58	1.70	. . . .
" . .	Springfield. . . .	. . . .	54.70	44.93	.20	.10	. . . .
Pa. . . .	Youngstown. . .	Carbon Limestone Co. .	96.43	.40	1.60	1.50	. . . .
" . . .	Norristown. . . .	Wm. Rambo.	53.49	45.76	. . . .	.70	. . . .
R. I . .	Lime Rock. . . .	Herbert Harris	88.23	8.79	.32	2.74	. . . .
W. Va	Marlow	G. C. Ditto.	. . . .	.98	.26	.18	98.44
Wis. . .	Hamilton.	Hamilton Stone Co.	54.25	44.48	.10	.67	. . . .

Marble.—Marble, which is a crystallized limestone, or a pure form of carbonate of lime, is an earlier formation of limestone which was formed with a pressure, and which retained the carbonic acid. Marble is the name usually given to any limestone which will take a good polish. The marble quarries of the U. S. are fast being developed, and are now furnishing the larger part of the marble used in this country. The table on page 41 will show the value and purposes for which produced, of the various marble-producing States for the year 1901.

The most used marbles of this country are the white, blue-grays, and greenish grays of Vermont, used mainly for interior and monumental work; the red or chocolate and white-mottled dolomitic varieties ("Winooski" marble), which come from Mallet's Bay, Vt. A white granular dolomitic marble from Lee, Mass., is used for building purposes. The United States Capitol at Washington is built of this marble. A coarse "snowflake" marble comes from Westchester County, N. Y., and is

PRODUCTION AND USE OF MARBLE QUARRIED IN THE U. S. DURING 1901.

State.	Rough	Building.	Orna-m'tal.	Cemetery.	Interior.	Other.	Total.
Alaska	$1,500						$4,500
Arizona	300						300
Arkansas	200		$100				300
California	3,280	$1,550	1,812				6,642
Georgia	268,761	241,683	16,500	$207,305	$166,305	$36,000	936,549
Maryland	8,100	45,000		15,000			68,100
Massachusetts	63,556	26,220	3,700	9,560	15,051	8,459	126,546
Missouri				2,100			2,100
Montana				1,500			1,500
New Mexico	4,200	3,000	300	3,100			10,600
New York	2,367	132,943	4,900	204,289	28,000	6,660	379,159
Oregon				500			500
Pennsylvania	18,078	111,069		25,060	400	2,940	157,547
Tennessee	162,513	13,000		14,000	305,124		494,637
Utah	320						320
Vermont	53,892	659,200	94,450	1,452,434	493,607		2,753,583
Washington	1,600	2,358	4,814	14,044			22,816
Totals	591,667	1,236,023	126,576	1,948,892	1.008,482	54,059	4,965,699

much used for building. Pink, gray, and chocolate-brown and white-mottled varieties are found in Tennessee, and are used much for interior work. A coarse white and white-clouded marble comes from Georgia, which is used much for building and inside work. A black marble is quarried at Glens Falls, N. Y.

Georgia Marble.—The Georgia marble known as "Kennesaw" is a white marble whose separate crystals are nearly transparent.

The "Etowah" marble is formed of very small crystals, but in other respects has quite a similar structure to the "Kennesaw" marble. Every crystal in it, however, instead of being white is tinted a faint shade of amethyst, making a tinted marble.

The "Creole" is a banded or gray marble.

The following table gives the composition, strength, and weight of some of the various marbles.

Onyx.—Onyx is the name given to a stone of the same composition as marble, but which was formed by chemical deposits.

The name is given on account of the resemblance to the true onyx, which is a variety of agate. This stone is found in Mexico, Arizona, and California, and is of various shades and colors. It is used entirely for ornamental purposes.

Testing Stone.—When a stone comes from a well-known quarry, and the stone is known by its past use to be what is

CHEMICAL COMPOSITION, WEIGHT, AND CRUSHING STRENGTH OF VARIOUS MARBLES.

State.	Location.	Carbonate of Lime.	Iron.	Carbonate of Magnesia.	Insoluble.	W'ght per Square Foot.	Crushing Str'ng'h per Square Inch.
Cal.	Inyo	78.36	.017	21.79	2.6	......	29,000
"	Colton	92.9	......	4.5	2.6	......	9,350
"	Beulah	98.00	.04	.05	.06	......	......
Ga.	Cherokee	98.96	......	.13	.61	171	10,970
"	Creole	98.	......	.26	.50	172	12,078
"	Etowah	97.32	.26	1.60	.62	169	10,642
Ill.	Mill Creek	......	......	......	......	172	9,687
Md.	Cockysville	......	......	......	......	178	23,500
Mass.	Lee	69.64	......	27.98	1.00	......	18,047
"	Westfield	79.68	......	19.68	.20	......	21,820
"	Great Barrington	98.34	.14	.50	.38	......	10,910
"	Hastings	52.82	......	45.78	......	......	18,941
N. Y.	South Dover	77.29	......	20.25	.90	......	18,836
"	East Chester	......	......	......	......	179	13,500
"	Pleasantville	54.12	......	45.04	.10	......	12,692
"	Sing Sing	53.24	......	45.89	......	......	......
Pa.	Annville	95.10	.23	3.96	1.07	......	12,210
"	Montgomery (blue)	98.15	.54	.50	.77	180	18,000
Tenn.	East Tennessee	98.78	.26	.67	.08	......	15,750
Vt.	Proctor	98.37	.03	.77	.63	......	......
"	Rutland (white)	97.73	.59	......	1.68	166	10,746
"	Rutland (green)	85.45	14.55	......	......	......	......
"	Dorset	......	......	......	......	165	7,612
Va.	Montgomery	......	......	......	......	......	8,950
Wis.	North Bay	......	......	......	......	175	20,025

desired, there is no need of a test, but if it is from a new quarry, or is a stone that has not been tested, by use, it should be tested thoroughly before being used in any extensive work. This can be done by analysis, to find its composition, but some of the more simple tests are given below which will be of much benefit to the superintendent. As a rule the most dense and compact stones will prove the best for building purposes and to withstand the effects of the weather. If the stone absorbs much moisture, then it will be subject to the effect of frost or freezing. To ascertain the absorption powers of a stone, take cube specimens of the stone which have been thoroughly dried and weighed; immerse them in clear water for three or four days, then take them out, wipe them dry, and re-weigh them. The increased weight indicates the amount of water absorbed.

Effect of Freezing.—Take cube specimens of the stone, dry and weigh them, and then repeatedly saturate them with water and freeze them. The loss in weight will indicate the loss of stone by integration. A test can be made by immersing

RATIO OF ABSORPTION.

Kind of Material.	Maximum.	Minimum.	Average.	Kind of Material.	Maximum.	Minimum.	Average.
Granites.	1/150	0	1/750	Sandstones. . .	1/15	1/240	1/24
Marbles.	1/150	0	1/300	Bricks.	1/4	1/50	1/10
Limestones. . .	1/20	1/500	1/38	Mortars.	1/2	1/10	1/4

the stone in a concentrated boiling solution of sulphate of soda, and hanging them up in the air for a few days. The salt crystallizes in the pores of the stone and acts about the same as frost or freezing. The stone is to be weighed before immersing and after drying, and the difference indicates the amount lost by integration.

To see if a stone will withstand the atmosphere and gases of cities, soak a sample several days in a solution of water containing 1 per cent of sulphuric and hydrochloric acids. If there is any composition in the stone that will be dissolved by the atmosphere the water will become discolored.

To see if a stone contains clay, or earthy matter, pulverize a piece, put the powder in a bowl of clear water, and shake well; if the water becomes discolored it indicates the presence of clay or earthy matter in the stone.

A fresh fracture of a stone should show bright and clean. A dull-looking fracture indicates a "dry" or a stone that is liable to decay. The superintendent should notice all stone when being worked, and by the sound can usually tell if the stone is sound; if there is a clear ring when the stone is struck it is sound, but a dull sound indicates cracks or seams. In some stone are found "crowfoots," which are veins running through parallel to its bed, but which are not cemented tight, being filled with a sort of earthy material, the stone being held together by the "dovetail" nature of the seam. This is the main fault found with the limestone quarried at Carthage, Mo.

The superintendent should examine all stone before being set and reject any that contains seams or cracks. Where stone is quarried by blasting, the superintendent must be on the lookout for "powder" cracks, or shakes, as they do not show up very distinctly at first, and are hard to find.

The following regarding testing of stone is taken from the annual report of the United States Geological Survey for 1898–99.

Tests and Analyses of Stone.—In the selection of all kinds of material for structural use it is becoming more and more customary to test such material, and to make the final selection on the basis of results so secured. It is, of course, unnecessary to state that if a given material has already demonstrated its fitness for a certain use by years of experience with it in that capacity, no results of scientific test should be considered as in any way capable of offsetting these results of actual experience; but in a country as young as the United States enough time has not yet elapsed in the use of stone as a building material to afford, in more than a few cases, a sufficient amount of such knowledge as results from long-continued use. As an example of a stone already sufficiently well known not to require further special tests, Quincy granite may be cited. This stone, by its hardness and susceptibility to high polish, and the contrast offered between polished and hammered surface, has demonstrated its fitness for use as a monumental stone. Similar statements might be made in regard to Westerly granite and other long-quarried and well-known materials.

When, however, a new material comes up for consideration it is desirable to learn of its qualities by quicker processes than those which depend upon actual use. There have, therefore, been devised a number of methods of testing stone which may be quickly carried out and which are of various degrees of value, according to the nature of the stone tested and the use to which it is to be put. The practice of making these tests of stone is of such comparatively recent date that it can hardly be said that the particular tests are so well understood as to be beyond criticism either in regard to the nature of the test itself or in the method of carrying it out. There is, moreover, a great lack of agreement among testing experts, both as to what tests should be applied to a given stone and as to details in the methods of applying these tests. In some cases physical tests seem to be all that are necessary to furnish the needful information without any chemical analysis whatever. In other cases it is quite generally conceded that physical tests should be supplemented by more or less complete chemical analyses. At the present time the uses to which stone is put are quite different from those involving it as a structural material. Thus, limestone is used in enormous quantities for burning into lime and as a flux in metallurgical operations. Limestone for such uses may be taken from the same quarry that furnishes building

stone, and is thus quarried by the same methods as apply to the production of the building stone. It cannot therefore well be considered apart from that which is devoted to structural use. If limestone is to be burned into lime, it is of course evident that the physical strength of the stone so used is of no moment whatever, but a knowledge of the chemical composition is absolutely essential. The same idea applies to limestone to be used as a blast-furnace flux.

Again, although a stone to be used for structural purposes may show great physical strength, it may, nevertheless, contain minerals which, by decomposition from atmospheric agencies, may develop in the entire mass weaknesses that would in course of time make the use of the stone undesirable. To detect the presence of such minerals chemical analysis may be resorted to in some cases, or, better still, this, together with a microscopical examination of thin sections, by which it is possible to detect minerals as such, even though the amount present may be extremely minute. The application of microscopical examination as a means of studying stone in relation to its technical applications is of recent date and as yet is used only to a limited extent.

Among the tests most commonly applied to stone which is to be used for structural purposes is the crushing-strength test. This gives in general a good idea not only of the power of the stone to support without fracture the superstructure that may rest upon it, but also of the homogeneity and all-round durability of the material. Other tests of value include transverse strength, porosity, corrodibility, specific gravity, and resiliency.

PART II.

STONE LAYING, SETTING, AND CUTTING, MARBLE AND SLATE WORK, BRICKWORK AND BRICKLAYING, PAVING, ETC.

Stone Laying, Setting, and Cutting.—RUBBLEWORK.—This is the cheapest and most common of stonework, but is only used for foundation-, or cellar-walls, retaining-walls, and such like; stone suitable for this work can be obtained in almost any locality. Fig. 28 shows a piece of random rubblework in which there is no attempt made to lay the stone in courses.

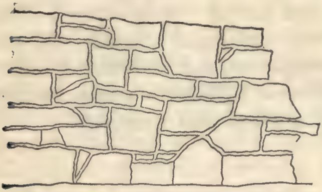


FIG. 28.—Random or Broken Rubble.

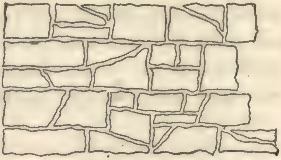


FIG. 29.—Rubblework Laid in Courses.

Fig. 29 shows a style of random rubble laid in courses from 16 inches to 30 inches in height. This is a good way to have a mason build any rubble wall where much weight is to rest on it, as he will have to level up at the top of each course, and start anew, and in this way he will build the wall more solid, and get more headers or bond-stones; also at each course he is sure to get level beds.

Fig. 30 shows a rubble wall laid in courses, with a bonding course AA between each course of wall; this makes a very

strong wall, as the bond course extends through the wall and ties it together.

Fig. 31 shows random-range work laid in level and broken courses. This is an improvement on the ordinary rubble wall;

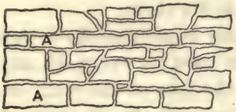


FIG. 30.—Broken Rubble, with Bond Courses *AA* Extending through the Wall, Makes a Very Strong Wall.

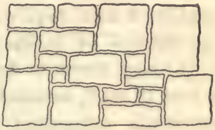


FIG. 31.—Random Range Laid in Level and Broken Courses.

in this the stones are dressed nearly square and with level beds, and do not require spalls for filling out the joints, as in ordinary rubble.

Fig. 32 shows the same work, but laid in courses, as in coursed rubble.

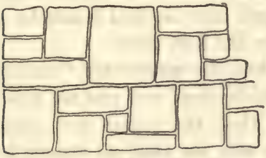


FIG. 32.—Coursed Random Ranged.

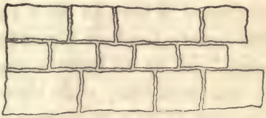


FIG. 33.—Block Coursed.

Fig. 33 shows block-coursed work, which makes the strongest of stone walls, as all the stones must be dressed to a given thickness and with level beds.

Fig. 34 shows a wall built of stone dressed in irregular form, with close joints, giving the wall a sort of rustic appearance; this is used only in dwellings or places where something "odd" or unusual is desired; it is expensive and requires great care in working, so that the joints will all have different directions, and not more than three to five centre at one place. The stone should all be about the same area on the face, and dressed so that all joints will be the same size. This is

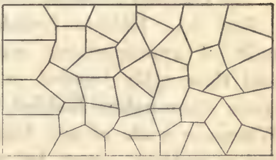


FIG. 34.—Stone of Irregular Form and Dressed to Make Joints.

one of the hardest designs of stonework to build, and will require the strict attention of the superintendent to get a satisfactory job.

Rubblework is often specified as "one-man" or "two-man" rubble, according to the size of the stone desired to be used and the number of men required to handle them.

In all rubble- or range-work the superintendent should see that a through stone or header is used to every six superficial square feet of wall, or one-fourth the face of the wall, consisting of bond-stone extending two-thirds of the distance through the wall from opposite sides and overlapping each other. The superintendent should watch the masons to see that each stone is bedded in a full bed of mortar, and that all cavities and spaces are filled solid. The way a mason usually fills up these holes is to gather up the spalls and dirt at his feet, throw this in the hole, and spread a little mortar on top. The only way to prevent this will be for the superintendent to pay close attention to the work, and as soon as he catches a mason at this have him take down that part of the wall and build it over again. When the mason has to do his work over several times he will learn that it is best to do it right in the first place.

The superintendent should see that the stones are "hammer-dressed," so as to have a face which does not project too far from the wall-line, and also see that the joints are such as can be pointed neatly; he should also see that all stones have a flat top and bottom bed, and that no round boulders or "nigger heads" are built in the wall. In building rubble the mason often tries to set the stone on edge, and fill in between with spalls, as he can build faster in this way than if he took the time to lay every stone on its flat. This way of building should never be permitted, as it makes a very poor wall.

The Chicago Building Code says:

Sec. 85. Rubble foundations and rubble walls must be built of approximately square and flat bedded stones, well and thoroughly bonded in both directions of the walls, each stone thoroughly bedded in mortar under its entire area. Wherever walls of any kind are used as curb walls, their exterior surfaces must be rendered approximately water-tight by a coating of a standard cement mortar.

Cut-stone Work.—Ashlar.—The facing of a wall in stone, without any regard to the design or style of cutting, is

called ashlar. The following cuts show the most common methods of laying the stone.

Fig. 35 is regular coursed ashlar, in which the stones are all the same height. In all coursed ashlar-work the specifications should mention if the joints are to be carried plumb or not,

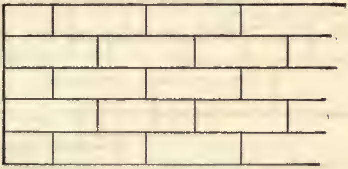
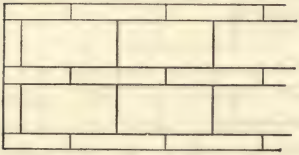


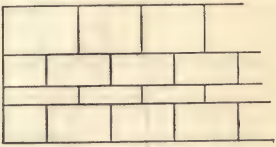
FIG. 35.—Regular Coursed Ashlar.

for, if it is not specified, there is a chance for argument on the part of the contractor. He may insist on the vertical joints being placed at random, as it is much cheaper, but does not make as nice a looking wall as when the joints are kept plumb.



Coursed Ashlar, two sizes

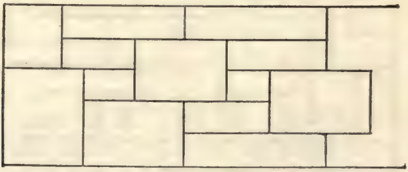
FIG. 36.



Irregular coursed ashlar

FIG. 37.

Fig. 36 shows coursed ashlar of two sizes. This is one of the cheapest methods of ashlar, as the large courses are usually but



Level and Broken Ashlar. Three sizes of stones.

FIG. 38.

4 inches in thickness and the small courses 8 inches, so as to get 4 inches bond in the wall.

Fig. 37 shows ashlar of irregular courses.

Fig. 38 shows level and broken courses. In this style of ashlar, care should be taken to keep the horizontal joints as short as possible; they should not be more than 3 or 4 feet in length.

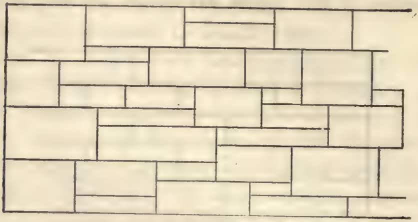


FIG. 39.—Random Ashlar.

Fig. 39 shows random ashlar, in which the plumb joints are set at random.

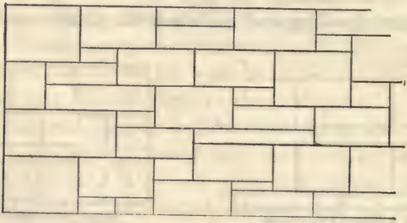


FIG. 40.—Random Ashlar, Plumb Joints.

Fig. 40 shows the same work improved by keeping the vertical joints plumb.

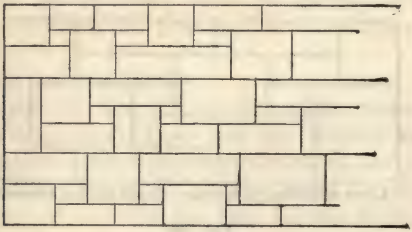


FIG. 41.—Random Ashlar in Courses.

Fig. 41 shows the ashlar divided into courses, 16 or 20 inches in height. To get a nice appearing wall in all random ashlar-

work, the superintendent must see that the different sizes of the stone are scattered through the wall as much as possible, and not have a lot of small-size stones or a lot of large ones built in at one place and adjoining each other. In all ashlar there should be a bond-stone to every 6 square feet of face of wall, or in coursed work every alternate course should be a bond course.

Fig. 42 shows regular coursed ashlar with chamfered and rusticated quoins.

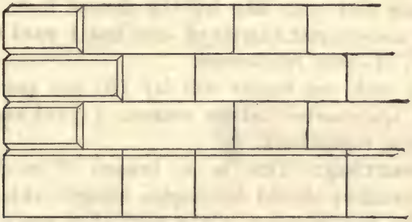


FIG. 42.—Regular Coursed Ashlar, with Chamfered and Rusticated Quoins and Chamfered Base.

Fig. 43 shows rusticated ashlar with moulded base and sill course. In ashlar-work the stones are usually sawed or dressed at the quarry to the different heights or thicknesses, leaving them to be cut to length at the job. Where the ashlar is in courses, it is customary in large work to have a working plan showing the size of each stone and the position of all joints. When such a plan is not provided or approved at the commencement of the work the size of the stone, location of the joints, etc., must be left to the judgment of the superintendent.

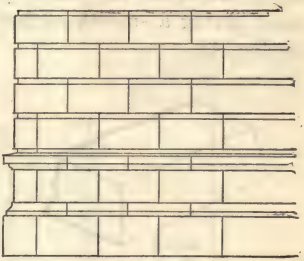


FIG. 43.

MEASUREMENT OF STONEWORK.—Rubble stonework is usually done by the perch, which is $24\frac{3}{4}$ cubic feet, or, as is more convenient, 25 feet; however, in some localities custom has made it a rule to call any number of feet from 16 to 25 a perch, according to the custom of the locality; so it is best when work

is done by the perch to have an understanding at the commencement how many feet are to be considered a perch. It is also well to have an understanding as to what openings are to be counted as solid or what are to be left out in measuring the wall.

In measuring stonework always measure from the outside, thus measuring all the angles twice.

All walls under 18 inches are counted same as 18 inches.

Ashlar and dimension or block stone are usually measured by the cubic foot; mouldings, belt courses, etc., by the lineal foot; flagging and such like by the square foot.

One and one-quarter barrels of lime and 1 yard of sand will lay 100 feet of stone rubblework.

One man with one tender will lay 150 feet per day.

One and one-quarter barrels cement, ¾ yard sand, will lay 100 feet stone rubblework.

Stone-cutting.—This is a branch of work in which the superintendent should familiarize himself with the various tools used by the cutters, and the method of using them, so to more readily determine between good and bad work, and also to know what tools should be used to produce the result desired. The stone when cut at the job will usually come in slabs, sawed on two sides, or perhaps in lengths, sawed four sides, giving a smooth surface to the beds and face, as shown by Fig. 44.

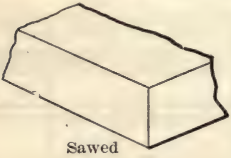


FIG. 44.

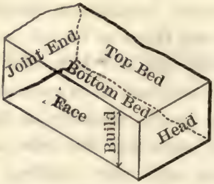


FIG. 45.

Fig. 45 shows the names of the different faces of the stone. Fig. 46 shows the various tools used by masons and cutters in dressing stone. *B* is the mason's or spalling hammer and is used to roughly square or dress a stone for rubblework. *C* is the mash-hammer used by cutters when using the point in roughing off and in working the harder rocks such as granite. *D* is the peen-hammer, which is used to smooth off the surface of a stone after using the point; it is sometimes used on

granite in place of patent hammer, but does not give as desirable a finish. *E* is the pick, which is used for dressing off stone for rough work, such as rubble or block course work

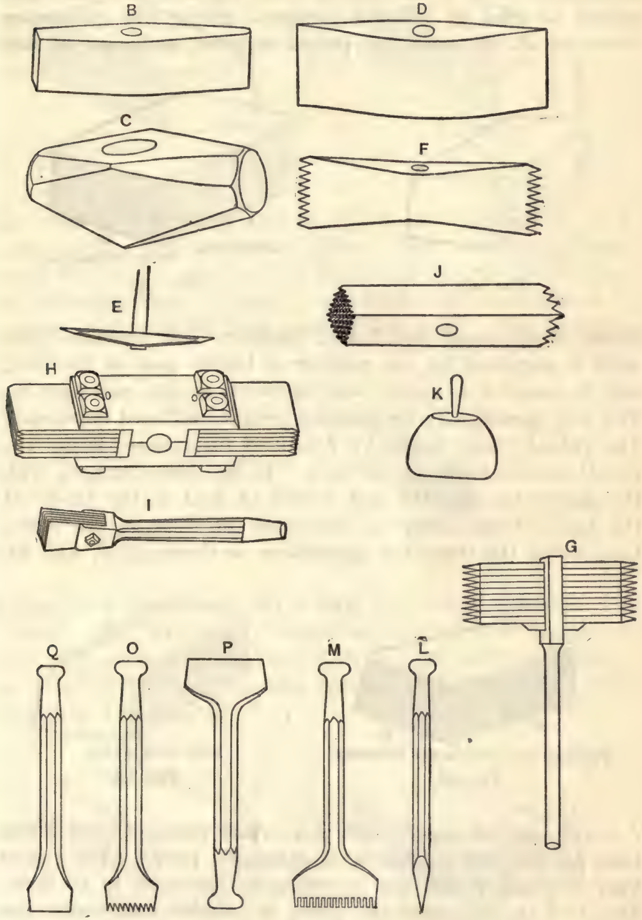


FIG. 46.

(Fig. 47). *F* shows the tooth-axe, which is used to bring the rough surface of soft stones to the desired plane, ready for the crandall, or tool; it is used also for dressing the beds of

stones. *G* is the crandall, which has a series of points fastened in a handle with a key; this is used on sandstones after the tooth-axe, and gives a smoother surface. Fig. 48 shows the appearance of a stone dressed with the crandall. The tool should be used in different positions, giving the appearance shown at *B*. *H* shows the patent hammer, composed of thin

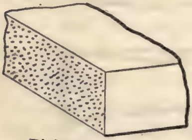


FIG. 47.

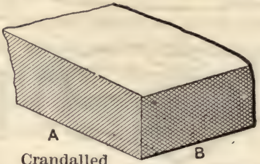


FIG. 48.

blades of sharpened steel bolted together. The fineness of the work is regulated by the number of blades used to the inch, and is specified as 4-cut, 6-cut, or 8-cut, as the case may be. This tool is used only for finishing granite and hard limestones. The patent chisel shown by *I* is used on surfaces where the patent hammer cannot be used. In finishing surfaces with the patent hammer the tool should be held so the blades of the hammer are always in the same direction on the stone. thus giving the stone the appearance as shown at *B*, Fig. 49,

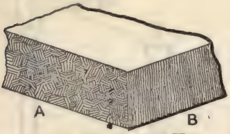


FIG. 49.

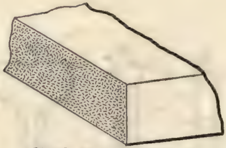
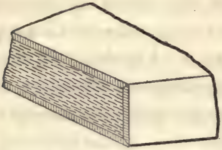


FIG. 50.

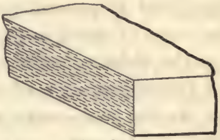
J is the bush-hammer, which is a square prism of steel whose ends are cut into a number of pyramidal points. The points vary in number and size according to the work to be done. This tool is used after the point or crandall and before the chisel in "drove" or "tooled" work. Fig. 50 shows the appearance of a stone after being bush-hammered. *K* is the mallet, which is used on the point or chisel when working limestone, sandstone, or any other soft stone. *L* is the point, which is

used to roughly dress off a stone, and is also sometimes used to dress the face of a stone as shown by Fig. 51. Fig. 52 shows



Rough Pointed with Draft

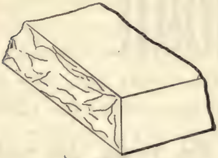
FIG. 51.



Fine Pointed

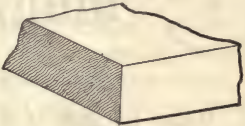
FIG. 52.

the same style of finish but on which more pains have been taken, giving it a smoother surface. *M-O* are tooth-chisels, which are used in working soft stones, as they cut faster than the ordinary chisel. *P* and *Q* are chisels, which are made of various widths for different parts of the work. Fig. 55 shows



Rock Face

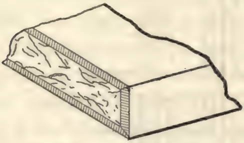
FIG. 53.



Tooled

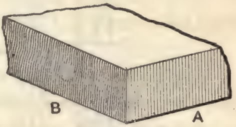
FIG. 54.

a stone with a rock face and a draft run around the edge with a chisel. Fig. 54 shows a stone on which a wide chisel has been used over its entire face; this is done before "droving" or "rubbing," and in limestone and sandstone the face is often finished in this manner.



Rock Face with Draft

FIG. 55.



Drove Work

FIG. 56.

Fig. 56 shows what is called "drove" work and is done with a wide chisel after the stone has been tooled and the char-

acter or fineness of the work regulated by the number of "bats," or blows, given the chisel to each inch in the length of the stone, usually 4.

The chisel is generally used across the stone, or lengthwise in the case of mouldings, etc., care being takeen to keep the cuts of the chisel parallel, as shown at *A*, Fig. 56. *B*, Fig. 56, shows the appearance of bad workmanship on the part of the cutter, as the tool-marks are all irregular and not straight and parallel.

Fig. 57 shows a piece of drove-work, showing the cuts of the

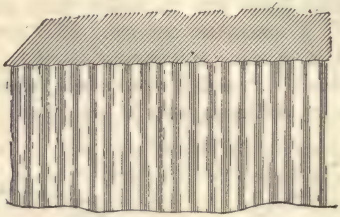


Fig. 57.

tool. Where the cutting is done at the quarry this work is usually done on a machine, and is always regular, but when done by hand requires great care.

Parallel lines should be marked out on the stone, as a guide to hold the chisel; one line to each two "bats" is sufficient. A template made of sheet iron or zinc is shown in Fig. 58,

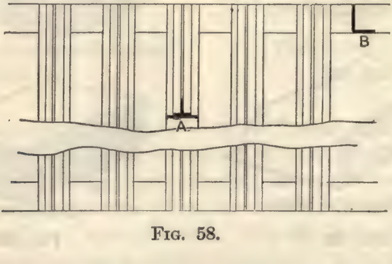


Fig. 58.

and is a very convenient tool for marking the stone for this kind of work. It is made, as shown, of a series of bars, *A*, sol-

dered or riveted to an angle, *B*, and is laid on the stone like a square and the lines marked off.

Where possible to do so, the superintendent should examine the stone in the rough, before being cut, so as to detect any flaws or imperfections, but, as is often the case, the cutting is done at the quarry, and the stone shipped ready to set; in such cases he should examine the stone as soon as it arrives, and promptly reject any which are not perfect as to quality or workmanship. He should see that the stones are being cut to the desired shape and size, and all mouldings and projections are cut as per detail.

In cutting mouldings, the cutter will very often change the shape or contour of the mould a little so as to make it easier to cut, and the superintendent must be on the lookout for anything of this kind. He should examine the stone for cracks or "drys" which may have been cemented up by the cutter, or patches cemented on where a corner has been knocked off. In every stone-yard will be found a bottle of shellac which is used for this purpose; in some of the white stones a little plaster of Paris will fill a crack or hole so that it is hardly discernible to the eye until the weather eats it out, and the superintendent should bear these points in mind when inspecting stone.

In regard to the cutting he should see that the finished face of the stone does not show marks from the tools used in roughing out the stone previous to finishing, for if the stone is not gradually brought to the desired finish by using the proper tools in succession, the marks of the rough tools will show through the finished face. In tooled work, if it is tooled without using the bush-hammer, the marks of the point, tooth-axe, or crandall will show, and in droved work, if it is not tooled before being drove, the marks of the bush-hammer will show.

In stone-cutting, the tools all should be used with moderate force, for with the tooth-axe, crandall, bush-hammer, etc., if the blow is struck too heavy, it causes the mark of the tool to penetrate the stone, causing a "sting."

In granite or hard stones, where the patent hammer is used, the superintendent must see that the finish is as fine or smooth as is desired. Often coarse work done with a coarse patent hammer, or with a peen-hammer, is sent to the job in place of fine patent-hammer work, and the superintendent should be able to readily judge between the two. He should examine all stones and see that the beds are cut at right angles to the

face; the tendency of the cutter is to cut the beds slack on the back, sometimes half an inch or more. This should not be allowed for the mortar-joint will then be one-fourth of an inch at the face and an inch and a quarter at the back of the stone, and will make a poor wall, for there will be more shrinkage in one and a quarter than in one-quarter inch of mortar.

The workmanship on all stone should be uniform, but at times the contractor will employ a poor workman, so the superintendent must see that all stones have a uniform appearance, and reject any not found perfect.

The superintendent should see that all stones, where required, are cut with the proper wash, and where necessary have a drip cut to throw off the water. In Fig. 59 at *A*, by undercutting, as shown, the arris will form a drip so all water will drop off at this point; if this is not done, the water will course down over the face of the stone to *B* before dropping off, and will always keep the stone covered with dirt and stain.

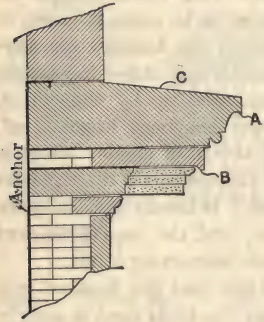


FIG. 59.

The wash on top of the stone, as shown at *C*, Fig. 59, while it need not be rubbed, as is the case with washes where exposed to view, it should be cut comparatively smooth, so that the dirt will not accumulate to be washed off with the rain, and if a wind is blowing, blow it against the face of the wall.

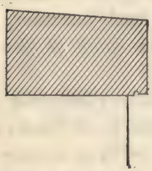


FIG. 60.

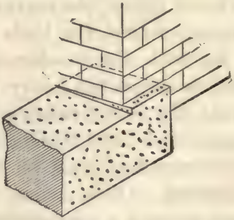


FIG. 61.

Figs. 60 and 61 show how the wash and drip should be cut on window-sills.

In ordinary work the wash is run the full length of the stone, as the work can then all be done with the saw, but on good work it should stop at the jamb as shown, having the top of the stone level, thus giving a level seat for the brickwork, which is not obtained when the wash runs the full length of the sill. Figs. 62 and 63 show how the wash should be cut on a sill

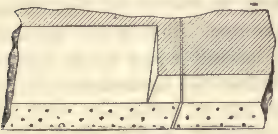


FIG. 62.

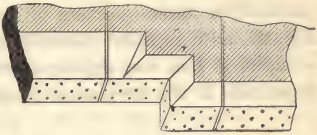


FIG. 63.

or belt course where the projections vary. These washes, where exposed to view, should always be rubbed smooth.

LINTELS.—In forming lintels over wide windows or other openings, it is advisable instead of using one long stone to use

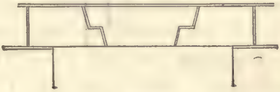


FIG. 64.

three stones, as shown by Fig. 64, which forms a sort of an arch. Or the stone can be notched over and hung on an I beam,

FIG. 65.

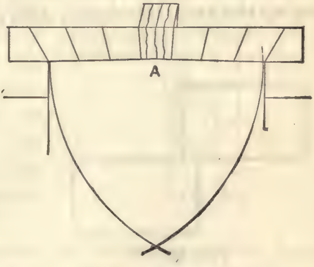


FIG. 66.

as shown by Fig. 65. Over very wide openings the stone should be cut to form a jack-arch, as shown by Fig. 66.

In cutting stone for an arch of any kind, or any stone on which a great pressure will be exerted, the stone should be cut so that the vein or natural bed of the stone will be at right angles to the pressure, as shown by Fig. 66 at *A*.

If the stone is cut with the vein parallel with the direction of the pressure, it is liable to split or scale off. In cutting stone for a jack-arch, the under side or soffet should be cambered one-half or three-quarters of an inch, as shown by Fig. 66 and Fig. 67, as it is more pleasing to the eye. If it is cut perfectly straight it has the appearance of having a sag in the centre, especially if the keystone drops below the arch-stone.

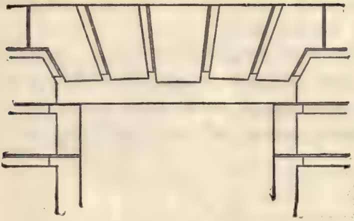


FIG. 67

FIG. 68.

In springing a jack-arch over a lintel, as shown by Fig. 67, the arch-stone should be notched over the lintel, as shown by Fig. 68, thus leaving the lintel free and nothing to carry but its own weight.

The superintendent should watch when this is done, that, in backing up the arch, the mason does not fill up the space between

FIG. 69.

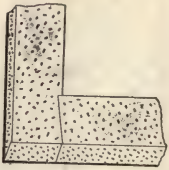


FIG. 70.

the arch and the lintel with mortar. If this should happen and there should be a slight settlement in the arch, the lintel would be broken.

STEPS.—Steps should be cut with a droop or wash of one-eighth or three-sixteenths of an inch, as shown by Fig. 69; this prevents the water from laying on them and makes them much easier to ascend than if they were level.

AREA COPING.—In cutting area coping, or any cap where there is any pressure from the side, it should be cut at the angle, as shown by Fig. 70, as this prevents the stone from moving.

CURBS.—In cutting curbing, the superintendent should see that the proper bevel or wash is cut on them, so that when set, the top of curb will have the same incline as the sidewalk. If cut square and set with an incline on the face, then the top of the curb will slope in the wrong direction and cause a valley to hold the water, as shown by Fig. 71.

FIG. 71.

FIG. 72.

FLAGGING.—When cutting flagging, the superintendent should see that the stones are cut square on the edges, so there will be the same width joint the full thickness of the stone. At times, instead of being particular about this, the cutter will pinch off the stone to the line and the stone wili have a feather edge, as shown by Fig. 72.

In cutting stone for and building walls, such as area walls, buttresss, etc., which will not carry a weight, or have a pressure exerted upon them equal to that on the main wall, which they adjoin, they should be built independent of the main wall and set in a chase or recess, as shown by Fig. 73. If built in this way the stone in the angle will not be broken by any unequal settlement.

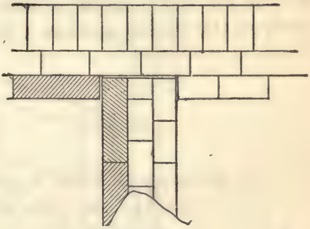


FIG. 73.

CARVING.—In carved work it is customary to furnish a model for the carver to work to, and it is the duty of the superintendent to see that the carving in the stone is a strict duplicate of the model. The carver will usually try to offer suggestions whereby he will claim he can improve the work, but as

a rule it will be a change for his own benefit, or so the work can be done quicker. He should be held strictly to the model and plans, unless, of course, in the judgment of the superintendent the work will be benefited or improved by a slight change. The superintendent must see that all arrises are cut sharp and all projections or cavities given their full dimension. The work should be brought out bold and well undercut to show a bold relief, and cavities cut so as to throw a shadow. This is the work the carver always tries to get out of doing, and will require the close attention of the superintendent.

Stone-setting.—This branch of work will require more attention from the superintendent of to-day than in former years, for by the rules of the trades unions nearly all stone setting is done by brick-masons who never learned the art of handling or setting stone. Accustomed as they are to slushing up joints in brickwork, they usually try to set stone by using three or four wedges to level up the stone and then try to slush mortar under it. Wedges are something a superintendent should not permit to be used, unless occasionally, when the mortar is soft, to keep a stone from settling too low, and then he will have to keep a sharp lookout, for if the stone happens to be a little low, the mason will just lift the stone a little with his bar and shove in the wedge to hold it up. The result of this is shown in Fig. 74; the stone rests on the wedge and has a hollow joint under half its bed.

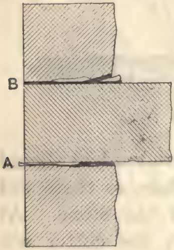


FIG. 74.

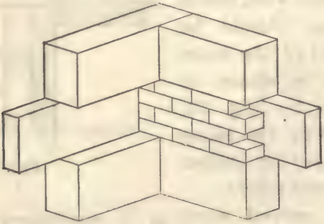


FIG. 75.

Fig. 74 at *B* shows a stone which has been cut with a slack bed, and the mason has wedged it up with a spall, leaving the

stone with no bed under the centre. The superintendent should insist on each and every stone being set in sufficient mortar so that the stone will have to be beat down to its bearing. In setting stone the mason will try to set three or four courses at a time, running in a course of brick to hold up the bond course, as shown by Fig. 75.

This will leave a vertical joint in the wall between the stone and the backing. The superintendent should not permit more than two courses of stone set in advance of the backing up; first a bond course and then a thin or ordinary course, as *AA*, Fig. 76; then he should have the wall backed up to this

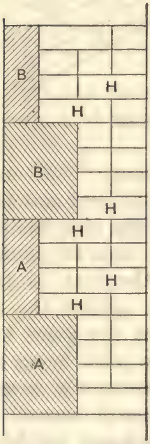


Fig. 76.

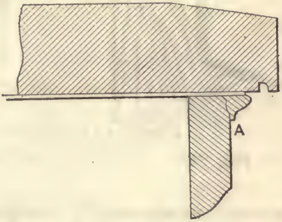


Fig. 77.

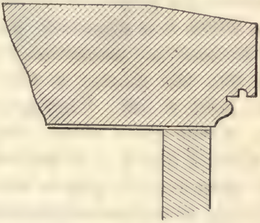


Fig. 78.

height, running in a header courses of brick as shown by *HH*, Fig. 76. Then the next two courses, *BB*, can be set and backed up in the same manner. In this way the ashlar and the brick work are firmly bonded together.

In setting stone the superintendent should see that all joints are raked out about three-quarters of an inch deep for pointing, and when a stone sets on top of a moulded projection, as shown by Fig. 77, the mortar should be kept back of the projection, if the joint is filled to the face of the moulding,

and should there be a little settlement the moulding is liable to be broken off as shown at *A*.

It is better to have such projection cut on the top stone, as shown by Fig. 78.

Fig. 79 shows a tool which the author has used with much success in slushing up vertical joints in stonework.

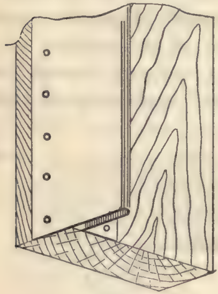


Fig. 79.

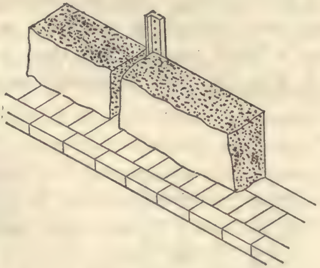


Fig. 80.

It is made, as shown, of a strip of wood about 1″×3″ and as long as desired, with a piece of sheet iron or zinc bent and nailed on as shown, the projection of the metal from the strip being the depth at which it is desired to leave the joint open for pointing. To use the tool this projection is inserted in the joint, as shown by Fig. 80; the mortar is then slushed in against the strip until the joint is full. This saves raking out the joint, keeps the face of the stone clean, and insures the joint being open to the desired depth. As will be seen by the way it is made, it can be used in the angles as well as on the face of the wall.

In setting all stones which are to carry a heavy weight, the mortar should be kept back far enough from the face of the stone so that there will be no danger of the corner being chipped off by the pressure on the stone.

The joint in cut-stone work should not be more than one-fourth inch, and for rock-face work not over three-eighths inch.

In setting projecting courses, such as cornices, etc., the stone when being set should be bedded but little beyond the face of the wall, as shown by Fig. 59, page 58, the balance of the joint being filled when the pointing is done; in this way every stone is responsible for its own weight and leverage, and the lower courses do not have to carry the weight of

the top stone. The stone in a cornice should always extend back in or through the wall, so that there will be weight enough in that part of the stone in the wall to overbalance the overhang or projection; then the top stone should be anchored as shown.

The top of the joints in the cap course of a cornice or other wide projection should be covered with lead, as shown by Fig. 81, the lead extending down into the joint about 2 inches,

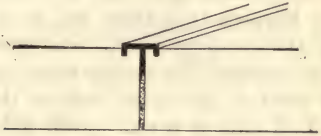


FIG. 81.

and over into channels cut in the stone as shown. Fig. 82 shows the section of a mould which the author has used for running

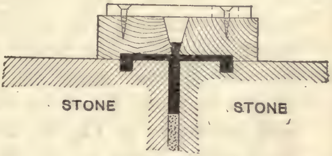


FIG. 82.

the lead hot into the joints, and made a very satisfactory job, much better than cementing the lead. By running the lead in hot, all the crevices and channels are filled solid and the lead takes hold of the rough surface of the stone and cannot get loose or come out.

It sometimes happens that after a stone is set it has to be moved a little; when this has to be done the superintendent must see that the stone is lifted and reset, for by shifting the stone it changes its position on the bed of mortar, and will not rest solid. As the stones are being set the superintendent should see that all joints are of the desired size. When a stone is a little long, and not room enough left for the vertical joint, the mason will likely say, "We will dress it off when we come to point it." The superintendent should never pay any attention to an assertion of this kind. It is much easier to cut

a little off the stone before it is set than to cut the joint out when it comes to pointing. When there is any cutting to be done to a stone it should be done before it goes into the wall.

The superintendent should have the stones, as they are being set, brushed clean, and wet with water so that the mortar will take hold of the stone. If the stones have been sawed on all sides, or on the top and bottom bed, he should have them gone over with the point or tooth-axe so as to roughen the surface a little to catch the mortar. He should see that all stones in a course member with each other, and that all mouldings join perfectly. It often happens that there will be a little difference in the shape of the stone or mould, and when the stones are set they will not member. In nearly every case of this kind the mason will want to go ahead and set the stone, saying, "We will dress it off after it is set." Now any promise of this kind is made with the idea that this little thing will be forgotten, and nothing more said about it, for it is two or three times costlier to do trimming of this kind when a man has to work from a ladder or scaffold than if he had the stone on the ground. The superintendent should have all trimming or cutting done as the work progresses, and before the stone is set. In setting the stone the superintendent should have the mason set each course to a pole, as shown by Fig. 83, as this will insure each course being set at the correct height and level.

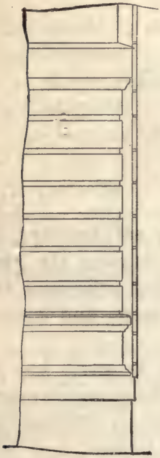


Fig. 83.

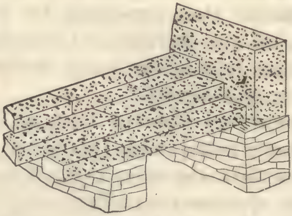


Fig. 84.

Steps.—Steps should be set as shown by Fig. 84, being carried on the wall at each end; in this way there will be no danger of breaking, in case there is any settlement, as would happen if the steps were bedded their entire length.

FLAGGING.—Stones for flagging or sidewalks should be set on a bed of broken stone or cinders extending below the frost-line, or a better method is to set them on dwarf walls, as shown by Fig. 85. After being set, the joints should be thoroughly filled with strong cement mortar, and the stone gone over and any irregularities at the joints dressed off.

FIG. 85.

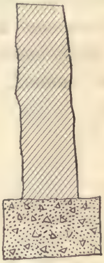


FIG. 86.

In setting a curb, it should be set on a bed of broken stone, and the curb itself be wide enough to extend below the frost-line, as shown by Fig. 86

Pointing Stonework.—The pointing of stonework is usually done as soon as the exterior part of the building is up, unless this part of the work is reached in cold weather, as no pointing should be allowed during weather when the mortar will freeze, either during the day or night. In extremely hot weather, if pointing is done it should be protected by hanging canvas or muslin over it to keep off the hot rays of the sun, as the heat will dry it too fast and the cement will lose its strength. All joints before pointing should be raked out at least three-quarters of an inch deep. The superintendent should have this done as the walls are built, as it can be done better while the mortar is soft than after the walls are up and the mortar set and hardened.

The superintendent should see that the mortar for pointing is mixed as desired, and all the joints filled and packed solid, and that they are thoroughly wet before the mortar is packed in them. The mortar for pointing should be mixed with cement and fine sand or marble-dust, so that the mortar will dress off smooth under the jointing tool.

Fig. 87 shows some of the different styles of pointing; with the designs *AA* the corner of the stone acts as a guide for the tool, but with raised designs the tool should be held against a straight edge; an ordinary short, straight edge with a couple of blocks tacked on the side to hold it up off the finished

joints answers the purpose, and the joints will all be made straight.

Before pointing the superintendent should have the work brushed off and washed down.

There are some stones which are damaged by acids, and the superintendent must determine this before having the walls washed. If acid does not damage the stone, a solution of dilute muriatic acid will neutralize the dirt and surplus mortar on the stone, and take it off very quickly. If there is any danger of acid affecting the stone, pure water must be used. Lye, pearline, etc., are also good for cleaning down some stone. As the stones are set, the superintendent should see that all moulds, etc., member, and the joints are kept the right size for pointing; this will save lots of trouble when the pointing is being done.

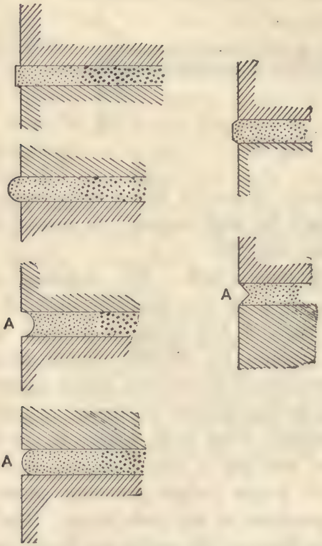


FIG. 87.

Marble Cutting, Finishing, and Setting.—Marble being but a high grade of limestone, the working or cutting of it is similar, the finished surface of marble usually being droved, tooled, or polished. Rock face, or any of the rougher finishes,

are seldom employed. In polishing marble, it is first rubbed with coarse sand on a rubbing-bed, then with fine sand and grit, then with pumice-stone, followed with Scotch bone, and last with putty-powder, which is used to give a gloss to the marble; oxalic acid is sometimes used with this powder, but a more durable polish is obtained without its use. Water is used in all the different steps of polishing.

Marble, when used for wainscoting, window-sills, water-closet partitions, etc., should be selected when got out so that the slabs will harmonize with each other in color and veining. For instance, two slabs of nearly the same veining are put up, as shown by Fig. 88, and give a very bad appearance; but if the same slabs had been got out so that they would have been put up as shown by Fig. 89, the heavy part of the veining would have come together and made a much more pleasing appearance.

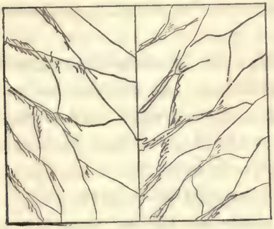


FIG. 88.

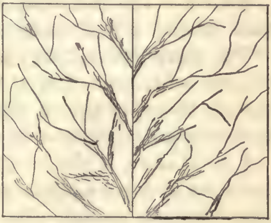


FIG. 89.

The superintendent should watch the marble as it is being set, and have it set so as to obtain as much harmony as possible; he should examine the marble to see if the polish is what is desired and all slabs are polished alike; he should also watch for cracks and stains. Marble when set against a wall is usually set in plaster of Paris and fastened with wire hold-fasts or anchors; these should be of heavy copper wire. The superintendent must see that a sufficient number of these are used to hold the marble firm and rigid, and that the slab is backed up with plaster of Paris so as to make it solid at each anchor. Where marble is fastened with bolts or screws they should be of brass and heavily plated with nickel or silver, as an iron screw will rust or stain the marble. Marble in floorwork should be set in Portland cement mortar.

In some colored marbles there are small cavities which have

to be filled with a wax when polished, and the superintendent should see that this is neatly done, so as not to be noticeable.

Marble Mosaic.—In this work the superintendent should see that the pieces of marble used are of nearly a uniform size and the cement joints between them show about the same. After the cement has set, the floor should be rubbed to a smooth surface and polished.

Terrazza.—In laying Terrazza floor the marble chips used should be small and nearly uniform in size and should be mixed with just enough neat Portland cement to fill the voids in the stone. As the chips will vary a little in size, the superintendent should see that the various sizes are evenly distributed throughout the floor and not have spots in the floor containing all large chips or all small ones. He should see that the floor is rubbed down sufficiently to show the chips uniformly throughout the floor.

Slate.—The principal use of slate is for roofing purposes, stair treads, urinal partitions, etc.

The slate for roofing purposes should be straight-grained, evenly split, and of a uniform thickness. It should be soft enough to cut or punch without breaking and still hard enough to firmly hold the head of the nail without it pulling through.

A good slate, when held up and struck with the knuckles of the hand or some metallic instrument, should give forth a sharp, clear, ringing sound. To test a slate as to its weathering qualities, especially in large cities where there is much smoke and gases, take a piece of the slate and immerse it in dilute sulphuric acid in a closed vessel for two or three days; at the end of that time if the slate is poor it will be softened and easily broken up, while a good slate will preserve its hardness. Another simple test for the absorptive power of slate is to stand a piece of the slate in a vessel of water for twelve hours and note the distance the water is absorbed up the slate from the water-level; in good slate the water will not rise more than one-eighth of an inch.

The presence of clay can be detected by breathing on a fresh piece of slate and observing if any clayey odor arises; the best slate will give out no odor whatever.

Some slates contain streaks of a hard material running through them which are called "ribbons"; this slate is usually sold as "ribbon slate," and at a reduced price. Any slate supposed to be No. 1 and containing any ribbons should be rejected.

Presence of Lime.—This can be determined by the application of cold dilute hydrochloric acid to the edges of a freshly quarried slate. Rapid effervescence implies presence of lime; slow, that of a lesser quantity of it or dolomite—carbonate of lime and magnesia.

Color and Discoloration.—The color of freshly quarried slate should be noted and compared with pieces exposed for several years to the weather. A good slate should retain its original color and not fade.

A good slate will have a fine grain, and the block from which the slates are split should be got out at the quarry, and split so that this grain will run lengthwise of the slate, so that should the slate ever crack with this grain it will be divided so there will be a nail in each piece.

The superintendent should see that the slates are all full size and have no broken corners. In putting them on he should see that the first course is doubled, and the bottom edge laid on a lath or strip, so as to give the slate the proper pitch so that the next courses will lay solid; each course should lay solid on the course below, so that the wind and weather cannot get under. To make a good roof it is advisable to lay the slate in a thin bed of cement paste or mortar; this costs a little more, but makes a perfect roof.

In slating up hips, etc., where there is no saddle to be used, the superintendent must see that the slater makes the proper lap with the slate and putties up each course with slaters' cement as he goes along. When finishing at the ridge or comb of the roof the slate should be cut, and not laid in a "stretcher" course, as is often done. In laying slates which are rough or of an uneven thickness it is hard to get each succeeding course to lay solid, and the slater will wedge up with a nail or small piece of slate; this should never be permitted, for the wedge is liable to work out and leave the slate loose.

Where slate is laid with a close valley, that is, where the slates are mitred in the valley and flashed each course, the superintendent must see that no broken or cracked ones are used, and that the flashing is large enough to insure a tight valley: such valleys should not be used on roofs under one-half pitch, for the rain or snow will be liable to blow up under the flashing.

The following table gives the strength, weight, etc., of some of the various slates.

STRENGTH, WEIGHT, ETC., OF SLATE.

State.	Location.	Crushing Strength per Sq. Inch.	Weight per Cubic Foot.	Porosity.	Per Cent of Loss by Corroding.
Maine.	Monson.	19.510	....	....	....
Maryland.	Peachbottom.	11.250	....	....	....
Pennsylvania ..	Albion.	7.150	173	.338	.547
" ..	Old Bangor..........	9.810	173	.145	.446
" ..	Peachbottom.	11.260	180	.224	.226
Vermont	Rutland Co.	10.975	....	.260	.350

Slate for wainscoting, stair-treads, etc., should receive the same attention as described for marble in like places.

TABLE SHOWING SIZES OF SLATES, THE NUMBER OF PIECES IN A SQUARE, AND HOW MUCH SHOULD BE EXPOSED TO THE WEATHER ON THE ROOF, ALLOWING 3 INCHES LAP

Size of Slate.	Number in Each Square.	Exposed When Laid.	Distance of Lath.	Size of Slate.	Number in Each Square.	Exposed When Laid.	Distance of Lath.
Inches.		Inches.		Inches.		Inches.	
24×14	98	10½	10½	16×10	222	6½	6½
24×12	115	10½	10½	16×9	247	6½	6½
22×12	126	9½	9½	16×8	277	6½	6½
22×11	138	9½	9½	14×10	261	5½	5½
20×12	142	8½	8½	14×8	327	5½	5½
20×10	170	8½	8½	14×7	374	5½	5½
18×12	160	7½	7½	12×8	400	4½	4½
18×10	192	7½	7½	12×7	457	4½	4½
18×9	214	7½	7½	12×6	533	4½	4½
16×12	185	6½	6½				

To determine the number of pieces to a square of any size slate not given, first deduct 3 inches from the length; divide this by 2; multiply by the width of slate and divide the result into 14,400.

An example—20×10 would be calculated thus: $20-3=17$; divided by $2=8\frac{1}{2}$; $8\frac{1}{2}\times10=85$; 85 divided into $14{,}400=169^{41}/_{100}$ pieces.

The weight of the various thicknesses of slate per square foot is as follows:

Thickness of slate in inches.	⅛	3/16	¼	⅜	½	⅝	¾
Weight per square foot in pounds.	1.81	2.71	3.62	5.43	7.25	9.06	10.88

The above is the weight of the slate of the thickness given. To find the weight when the slate is laid, the lap and surface exposed to the weather must be considered.

TABLE SHOWING QUANTITY OF NAILS NEEDED TO LAY ONE SQUARE OF SLATE.
(The quantity given is from actual count.)

Sizes of Slate.	No. to Square, 3-inch Lap.	Weight of Nails to a Square.													
		3d.								4d.					
		Gal.		Tin.		Copper & Steel Wire.		Alumi-num Wire.		Gal.		Tin.		Copper & Steel Wire.	
		lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.	lbs.	oz.
24×14	98	1	2	...	15	....	14	....	6	1	6	1	2	1	4
24×12	115	1	5	1	2	1	1	....	7	1	10	1	5	1	7
22×12	126	1	7	1	4	1	3	....	8	1	12	1	7	1	9
22×11	138	1	9	1	5	1	4	....	9	1	15	1	9	1	11
20×12	141	1	10	1	6	1	5	....	9	2	...	1	10	1	12
20×10	170	1	15	1	11	1	9	....	10	2	6	1	15	2	2
18×12	160	1	13	1	9	1	8	....	10	2	4	1	13	2	....
18×10	192	2	3	1	14	1	12	....	11	2	11	2	3	2	6
18× 9	214	2	7	2	1	1	15	....	12	3	8	2	7	2	11
16×12	184	2	2	1	12	1	11	....	11	2	9	2	2	2	5
16×10	222	2	8	2	2	2	....	....	12	3	1	2	8	2	12
16× 8	277	3	2	2	11	2	8	....	15	3	14	3	2	3	8
14×10	261	3	...	2	8	2	6	....	14	3	10	3	...	3	4
14× 8	327	3	12	3	2	3	....	1	2	4	9	3	12	4	2
14× 7	374	4	4	3	10	3	7	1	4	5	3	4	4	4	11
12× 8	400	4	9	3	14	3	10	1	6	5	9	4	9	5	....
12× 7	457	5	3	4	6	4	2	1	9	6	6	5	3	5	11
12× 6	533	6	1	5	2	5	14	1	13	7	6	6	1	6	11

Bricks and Brick-laying.—The quality of a brick depends on the material used, the care in its manufacture, and the manner in which it is burned. With the machinery that is in use at the present time it is possible to use different materials and make better brick than in former days when clay was the only material used and the bricks were moulded by hand.

For common bricks, a shale rock makes perhaps the best brick, and when burned with gas, as quite a number are now burned, they make a very hard brick and of uniform size and color.

The chemical compounds contained in the material used determines the color and quality of the brick to a great extent; if there is much silicate of lime in the material used, it renders the clay too fusible and causes the brick to soften and warp or twist in burning. A small amount of sand is beneficial, as it tends to prevent shrinkage from the heat in burning.

Iron gives hardness and strength to the brick, and also causes the red color in burning, the color depending a great deal on the amount of iron contained.

In face or front brick iron or mineral pigments are sometimes added to the clay so as to color the brick as desired.

Where the bricks are exposed to excessive heat in burning, the iron fuses and produces a dark-blue or purple color, as shown by the "arch" or clinker brick next to the fire in the kiln.

When the clay contains much magnesia with the iron it produces a yellow color.

NAMES OF BRICK.—All brick not hard enough to stand in the outside of buildings are known as "salmon" or "soft" brick.

All brick hard enough for the outside of buildings, but not selected or graded, are known as "hard kiln run."

All brick set in the arches or benches of the kiln, and which are discolored, broken, or twisted in the burning are known as "arch brick."

All common brick selected for the outside of buildings are known as

$$\text{Front brick.}\left\{\begin{array}{l}\text{No. 1 light-burned.}\\\text{No. 2 medium-burned.}\\\text{No. 3 hardest-burned.}\end{array}\right.$$

All brick used for sidewalks are known as "sidewalk brick."

All the brick in the kiln not strictly soft taken together are known as "merchantable brick."

All brick that are set in the kiln when burned are known as "kiln-run brick."

Bricks moulded either by hand or machinery in rough, coarse sand and repressed without rubbing, so as to give the brick a rough sand finish, are known as "stock" or "sand-struck" brick.

All brick other than square are known as "ornamental brick."

All brick made either by the repress or dry-press process, and selected for fronts of buildings, are known as "press brick," which are: No. 1, light shade; No. 2, medium; No. 3, dark.

SIZES OF BRICKS.—The sizes of bricks vary much in different parts of the country, and when brick and stone are worked together the architect should know what brick he is going to use, so as to know its size and in preparing the drawings make the sizes of stone to suit the brick. The author has known of cases where the contractor had to ship brick several hundred miles, just because the brick which were made near the work was not of a suitable size to work with the stone as laid out and figured for the building. This is in regard to the face

brick, although the common brick should work with the stone so as to get the correct bonding. In English bond and English cross bond there is often trouble to get brick of a suitable size to work the bond correctly.

WEIGHT OF BRICK.—The weight of brick vary, according to size and their density, from 4½ to 5½ pounds; in the wall a cubic foot of brickwork will weigh about 115 pounds.

QUALITY.—The superintendent should examine the brick as brought to the work, and see that they are of the desired quality; they should be uniform in size and color and hard and well burned. When two bricks are struck together they should give forth a clear ringing sound. When broken with a hammer they should break across the brick, dividing it into two "bats," and produce a clean fracture showing a compact, hard structure, having a bright surface free from cavities and air-holes. A soft brick when broken will usually fly into several pieces.

The brick should have square edges and parallel surfaces, and not be twisted or warped by burning.

A brick should not absorb more than one-tenth of its weight of water.

As a rule the darkest bricks are the strongest and best burned, while the light-colored ones are usually soft and will not stand much crushing strain or the weather. A good test for a brick is to heat it red-hot and then pour cold water on it; if it does not crack or break it is of excellent quality.

SPECIFIC GRAVITY, WEIGHT, AND CRUSHING STRENGTH OF BRICK.

Name.	Specific Gravity.	Weight per Cubic Foot in Pounds.	Crushing Strength per Square Inch in Pounds.
Best pressed	2.4	150	5000 to 14973
Common hard	1.6 to 2.0	125	5000 to 8000
Soft	1.4	100	450 to 600

The New York Building Code gives the working strength of brickwork as follows:

	Pounds per Square Inch.
Brickwork in Portland-cement mortar; cement, 1; sand, 3	208
Brickwork in lime and cement mortar; cement, 1; lime, 1; sand, 6	160
Brickwork in lime mortar; lime, 1; sand, 4	111

A good brick supported at each end on supports 6 inches apart should withstand a pressure at the centre of 2000 pounds without breaking.

In a test made by Norcross Bros. of Boston the crushing strength of brick ranged as follows: 2720 pounds for light hard, the poorest; up to 8000 pounds per square inch for the best quality to produce the first crack; while the ultimate strength ran from 3149 up to 10,532 pounds per square inch.

FIRE-BRICK.—Fire-brick are made by a similar process to making ordinary brick, but from different material. The clay used is known as fire-clay. This clay is composed of hydrated silicates of alumina, associated with silica and alumina in various states or subdivisions and sufficiently free from alkalies, iron, and lime to resist vitrification at high temperature.

Oxide of iron or sulphate of iron in the clay is very injurious, and when found in the brick in a quantity of more than 5 per cent they should be rejected. Lime, soda, potash, and magnesia, are also injurious and any fire-brick containing over 3 per cent of either should be rejected.

Good fire-clay should contain 50 to 80 per cent of silica and 18 to 35 per cent of alumina; it should be of a uniform texture and have a greasy feel between the fingers.

Fire-brick which are to be exposed to heat should be laid in fire-clay, and should be thoroughly wet before laying; the mortar should be used very thin and the joint made as tight as possible.

VITRIFIED BRICK are brick burned to a hard glossy consistency so as to be impermeable to water and fit for damp-proof work, paving, and such purposes.

BRICK-LAYING.—This is one of the branches of work that will require the close attention of the superintendent, as it is one that can be slighted at any time and a defect covered up in a moment. If in making his rounds of the building the superintendent should notice a brick-mason hurriedly spreading mortar over the top of the wall or a course of brick just laid, he should regard it with suspicion, and it would be well for him to examine this particular part of the wall. The strength and stability of a wall depends, in addition to the quality of the materials used, upon the manner in which it is built. The superintendent should first see that the bricks are hard, sound, and of correct shape, and that they are all thoroughly wet before being laid in the wall, so that they will not absorb the water out of the mortar, thus causing it to lose its strength. The mason will often complain that wetting the brick makes

them hard to lay, or that they will "creep." The superintendent should pay no attention to this, for a brick will have to be soaked in water until it will absorb no more before it is too wet to use. When the bricks are being laid the superintendent should see that they are all laid on a full bed of mortar, and where possible should be shoved or rubbed into position, and he should also see that all vertical joints are filled solid with mortar.

It is the custom of masons to spread the mortar, then lay on the brick, exerting no pressure on the brick except its own weight. The superintendent should watch for this and compel the mason to shove or force each brick down to a solid bed and close joint.

The vertical joints should all be completely filled with mortar and the brick kept at least ¼ inch apart for this purpose, as shown by Fig. 90 at *A*. Fig. 90 at *B* shows how the mason will want to lay the brick tight against each other with a dry joint.

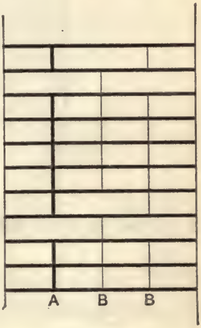


Fig. 90.

The face of a wall where the mason has his own way will usually be laid as shown in Fig. 91. He will spread the mortar and with his trowel gather up the overhanging mortar and scratch it off on the end of the brick already laid, then lay the next brick against this mortar. Often there will only be enough mortar to fill the joint half an inch deep, and this will be all it will ever get unless the superintendent compels the mason to fill it. The superintendent must see that these joints are completely filled and not left as shown in Fig. 91.

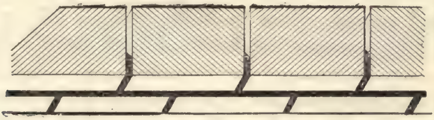


Fig. 91.

In spreading mortar for the outside courses, the mason will stretch it along the top of the brick already laid, and then run the point of his trowel through the centre, leaving it as shown by Fig. 92.

Unless the superintendent watches to see that enough mortar

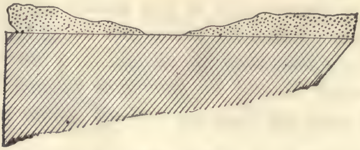


FIG. 92.

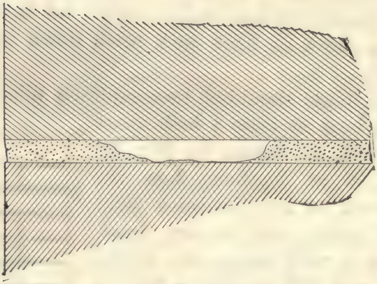


FIG. 93.

is spread to give the brick a full bed, the chances are that the brick will be bedded only a little on each side, as shown by Fig. 93. This is often a defect in laying front brick with "butter" joints; the mortar is placed on the brick to be laid in the manner shown by Fig. 94, and when laid the result is shown by Fig. 95, leaving the centre of the brick without any bed.

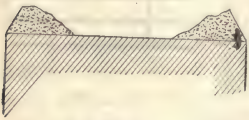


FIG. 94.

The author has seen work of this kind where the weight of the wall had caused pieces of brick to spall off, as shown at *A*, Fig. 95, just because the brick did not have a full bed of mortar.

The bed joints for common brickwork should be about $\frac{3}{8}$ inch, but depend a great deal on the mortar used. The superintendent can tell by watching a few bricks laid, and noticing the pressure required to get a solid bearing, what size joint should be used. In "stock" or "sand-struck" brick for outside work the joint should be $\frac{1}{4}$ inch, and for "press" brick $\frac{1}{8}$ or $\frac{3}{16}$ inch.

The superintendent should see that the bricks, as laid, are

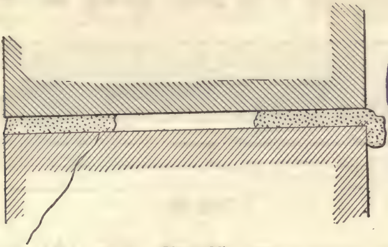


Fig. 95.

set level. The custom of masons is to set the brick with a slight incline, as shown by Fig. 96, as this gives them a projection on the lower course to guide the trowel in striking the joint. The face of the bricks should be kept as near plumb as possible and no unnecessary projections made to catch the water.

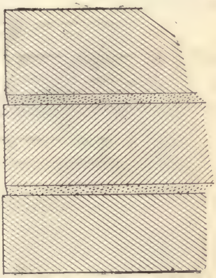


Fig. 96.

Bond is another point in brick-work that requires the close attention of the superintendent. It is usually specified that every fifth or sixth course, as the case may be, shall be a header, and it is the duty of the superintendent

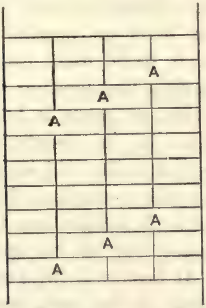


Fig. 97.

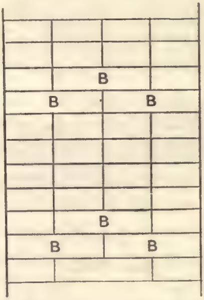


Fig. 98.

to see that this is strictly carried out, and that each header course is lapped through the wall, as shown by Fig. 97 or Fig. 98.

In facework, where it is not desired to show the headers, they are usually put in as shown by Fig. 99. This is called

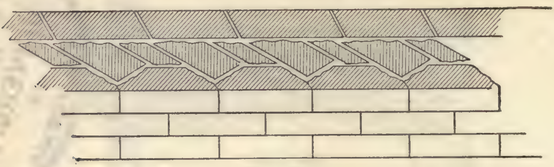


FIG. 99.

clipped or diagonal secrete bond. Fig. 100 shows another style of secrete bond; the stretcher course is clipped to half its width, and a three-quarter bond course laid behind, as shown.

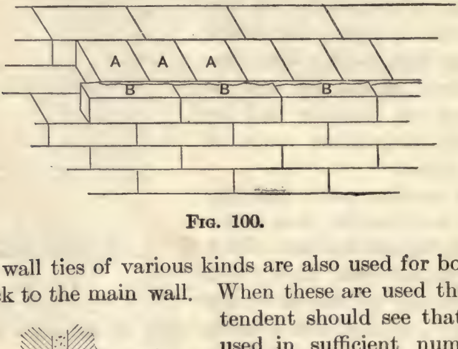


FIG. 100.

Metal wall ties of various kinds are also used for bonding the face brick to the main wall. When these are used the superintendent should see that they are used in sufficient numbers, and the two courses of brick brought as near level as possible where the tie is to be used. *A* in Fig. 101 shows a bad method of using these ties, as there is too much difference in the height of the courses; *B* in Fig. 101 shows how they should be used, as the strain on the tie is tensile and there is no chance for it to spring or give. At best wall ties are a very poor method of tying the face of a wall to the main structure, and the author cannot recommend their use.

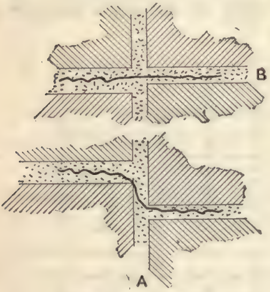


FIG. 101.

The strongest wall is obtained when header courses are used in the face of the wall. Fig. 102 shows the common form of

bond in which a header course is run at intervals of, say, every six courses. This header course should be started with a quarter or three-quarter brick, as shown at *A* and *B*, of which that at *A* looks the best.

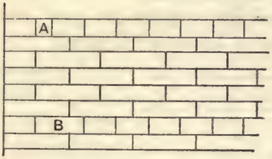


Fig. 102.

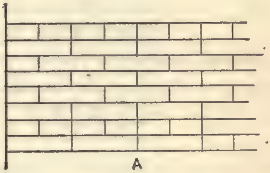


Fig. 103.

Fig. 103 shows the wrong way of starting, and brings three vertical joints over each other, as shown at *A*.

Fig. 104 shows what is known as Flemish bond, in which every alternate brick is a header. In this style of work every alternate course should have headers of full brick, and not "bats." The mason will try to work in as many "bats" as possible so as to save face brick, and it will require watching on the part of the superintendent to prevent it.

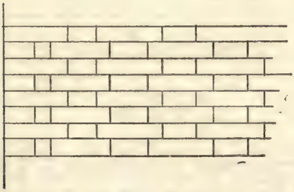


Fig. 104.

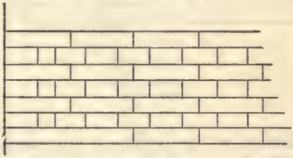


Fig. 105.

Fig. 105 shows English bond in which every alternate course is a header course; in this work every sixth course of brick should be a full header course. English cross-bond shown by Fig. 106 is similar to the English bond, except that each alternate stretcher course breaks joints with the stretcher course below. This divides the face of the wall up into St. George's crosses, as shown by 1, 2, 3, Fig. 106, and makes a very pleasing appearance to the eye.

Fig. 107 shows how this work should be carried around quoins, etc. In all facework it will be the duty of the superintendent to see that the mason keeps his joints plumb and in

line. Fig. 108 at *A* shows the distorted appearance of a wall laid in English cross-bond, in which the joints were not kept plumb. Fig. 108 at *B* shows the work as it should be.

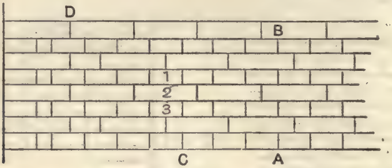


FIG. 106.

The author has often found it necessary to have the mason mark out a pole, as shown by Fig. 109, and mark on it the

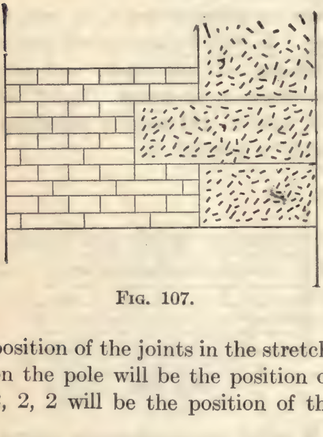


FIG. 107.

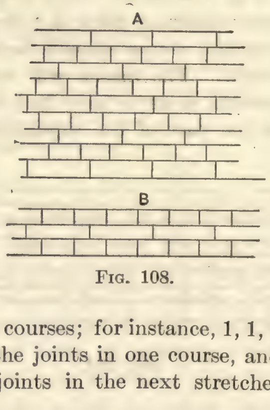


FIG. 108.

position of the joints in the stretcher courses; for instance, 1, 1, 1 on the pole will be the position of the joints in one course, and 2, 2, 2 will be the position of the joints in the next stretcher

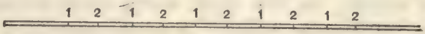


FIG. 109.

course. The pole should be made so that one end of it can be held at the corner of the wall or pier, so that it will always be held in the same position. After the header course is laid the pole should be used and each joint of the stretcher course marked off; after the stretcher is laid the header course can be centred with the eye; then repeat the operation for the next stretcher.

The joints should line up, as shown at AB, Fig. 106, and form a true diagonal step, as shown from C to D.

The superintendent should instruct the foreman of the work how he desires to have the work done, and any work not done correctly, have it taken down and done over; this is the only sure way of making brick-masons do perfect work.

In backing up stone ashlar or other like work, the superintendent must see that the bond courses in the brickwork are built in at the proper place to bond with the stone, as shown by Fig. 110.

In finishing to the top of a thin course of stone the last course

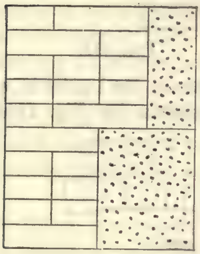


Fig. 110.

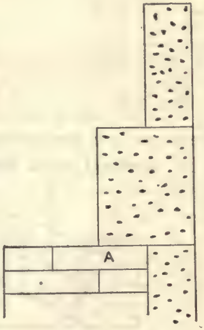


Fig. 111.

of brick should have a header, as shown at A in Fig. 111, so that the next course of ashlar will lap onto it and form a bond with it.

The superintendent should never allow more than two courses of stone set ahead of the brick-mason; first a thick or bond course, and then a thin one, as shown by Fig. 111. Then the mason can back up these two courses, as shown by Fig. 110, when the wall will be ready to set two more courses of ashlar.

Unless the superintendent cautions the mason against it, they will run up three or four courses of ashlar by filling in a course of brick, as shown by Fig. 112. This should never be permitted, as it makes a vertical joint through the wall, as shown from A to B.

The superintendent should occasionally, as the walls are being built, sight along and down the face of them, to see if they are

being built straight and plumb; some masons will keep working "hard" against the line until they have the wall considerably out of plumb.

FIG. 112.

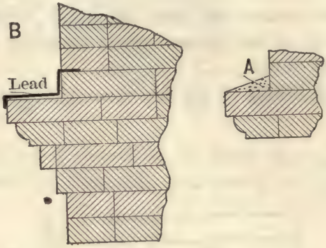


FIG. 113.

Where there are projection courses in the outside wall, they should be covered with lead, as shown by Fig. 113*B*; some-

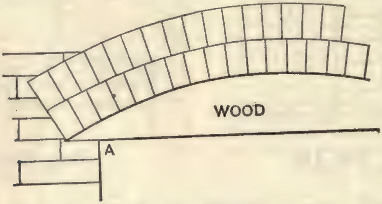


FIG. 114.

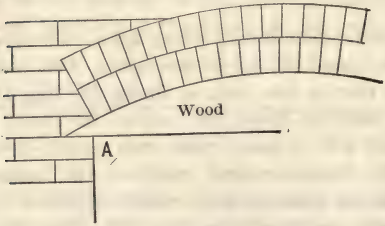


FIG. 115.

times they are covered with cement mortar, as shown by Fig. 113*A*; this is not so reliable as the lead, for the cement may crack and work loose.

In turning arch lintels over door or other openings, it is customary to use a wood centre, as shown by Fig. 114. The superintendent should see that the arch is started at the end of the wood centre, as shown by Fig. 114, and not as shown by Fig. 115, as this throws the weight onto the wood.

Arches are usually built of concentric rings or header courses, as shown by Fig. 116. Where the arch is to carry a heavy load

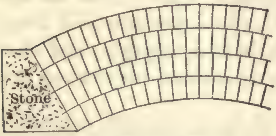


FIG. 116.

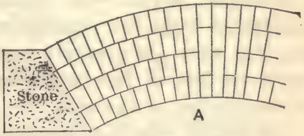


FIG. 117.

it is advisable to tie the courses together, as shown at *A*, Fig. 117. When an arch springs off an outside wall or pier, or where there will be nothing to counteract the thrust of the arch, it is advisable to build in an I beam, as shown by Fig. 118, and have it anchored solid top and bottom with a bolt or rod extending back into the main wall.

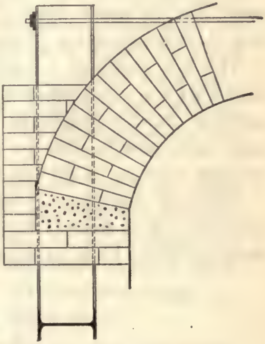


FIG. 118.

Where there are chases or recesses for pipes or vent flues to be built in the wall, the superintendent should see that they are located correctly, and that they are built straight and plumb; these chases or recesses should be shut off at each floor level after the pipes are in place, and before plastering, so as to prevent any egress from floor to floor in case of fire.

Where walls are built to any great height or length with nothing to brace them, the superintendent should have them braced temporarily until the mortar hardens, or until the floor-beams are put in place.

In narrow buildings where an engine and elevator are used for hoisting the superintendent should see that the strain from the platform to the engine is lengthwise of the building. The author saw a case where a six-story building had to be taken

down when the walls reached the sixth floor, because the engine and elevator had been set crosswise of the building, and the strain and vibration caused the walls to "creep" until they were 6 inches out of plumb.

The superintendent should see that all walls are protected from the weather as they are being built, and covered every night, especially front or outside walls.

HOLLOW WALLS.—In building hollow walls, such as are sometimes built for ventilation, etc., the superintendent must see that they are properly anchored or tied together, and that holes are left at the bottom so the space can be cleaned out at completion of the wall.

CHIMNEYS.—In building chimneys the superintendent must see that the flues are built straight and with as few bends as possible, and that all joints in the brickwork are slushed full of mortar, and where flue-lining is not used, see that the inside of the flue is plastered smooth. The top of a chimney above the roof should be laid in cement mortar. When the chimney is completed, the superintendent should have a weight dropped down each flue to make sure that it is open its entire length, and not stopped up with "bats" and mortar.

The face walls of a building at completion should be washed down with a solution of diluted muriatic acid and all dirt and surplus mortar removed; all open joints left under window-sills, etc., should now be pointed, care being taken to use just enough mortar to fill the face of the joint.

HEARTH ARCHES.—"Trimmer" or "hearth" arches for the support of a hearth stone or tile are usually built of brick and should be built as shown by Fig. 119; this throws the weight

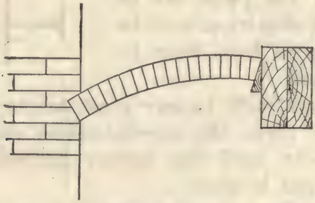


FIG. 119.

and thrust nearly all on the chimney and not on the wood joist. A flat wood centre is often used in frame houses, as shown

by Fig. 120; but the author does not consider this a good method, for the wood in the recess in the brickwork is but $2\frac{1}{2}$ or 3 inches away from the flue, which is too close for safety. Where centres

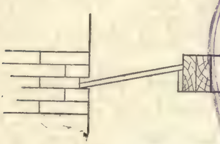


FIG. 120.

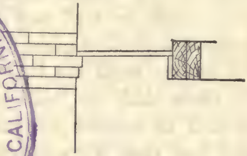


FIG. 121.

of this kind are used it is better to corbel out, as shown by Fig. 121; this will give 4 inches of brick between the wood and the flue.

BRICK NOGGING.—In wooden partitions it is often specified for a course of brick to be built in at the bottom of the story, and also at half height, resting on the bridging; this is to prevent the passage of vermin and also act as a fire-stop. The superintendent should see that the brick used in such cases are not wider than the studs, so the lathing can be nailed on straight; where the joist rests on a partition it is well to build "nogging" from the top of this partition to the top of the joist.

WALLS, PIERS, AND PARTITIONS.—The following, taken from the New York Building Code, 1901, is a very good guide for the superintendent:

Sec. 27. *Materials of Walls.*—The walls of all buildings, other than frame or wood buildings, shall be constructed of stone, brick, Portland-cement concrete, iron, steel, or other hard, incombustible material, and the several component parts of such buildings shall be as herein provided. All buildings shall be inclosed on all sides with independent or party walls.

Sec. 28. *Walls and Piers.*—In all walls of the thickness specified in this code, the same amount of materials may be used in piers or buttresses. Bearing walls shall be taken to mean those walls on which the beams, girders, or trusses rest. If any horizontal section through any part of any bearing wall in any building shows more than 30 per centum area of flues and openings, the said wall shall be increased 4 inches in thickness for every 15 per centum, or fraction thereof, of flue or opening area in excess of 30 per centum.

The walls and piers of all buildings shall be properly and

solidly bonded together with close joints filled with mortar. They shall be built to a line and be carried up plumb and straight. The walls of each story shall be built up the full thickness to the top of the beams above. All brick laid in non-freezing weather shall be well wet before being laid. Walls or piers, or parts of walls and piers, shall not be built in freezing weather, and if frozen, shall not be built upon.

All piers shall be built of stone or good, hard, well-burnt brick laid in cement mortar. Every pier built of brick, containing less than 9 superficial feet at the base, supporting any beam, girder, arch or column on which a wall rests, or lintel spanning an opening over 10 feet and supporting a wall, shall at intervals of not over 30 inches apart in height have built into it a bond-stone not less than 4 inches thick, or a cast-iron plate of sufficient strength and the full size of the piers. For piers fronting on a street the bond-stones may conform with the kind of stone used for the trimmings of the front. Cap-stones of cut granite or bluestone, proportioned to the weight to be carried, but not less than 5 inches in thickness, by the full size of the pier, or cast-iron plates of equal strength, by the full size of the pier, shall be set under all columns or girders, except where a 4-inch bond-stone is placed immediately below said cap-stone, in which case the cap-stone may be reduced in horizontal dimensions at the discretion of the Commissioner of Buildings having jurisdiction. Isolated brick piers shall not exceed in height ten times their least dimensions. Stone posts for the support of posts or columns above shall not be used in the interior of any building. Where walls or piers are built of coursed stones, with dressed level beds and vertical joints, the Department of Buildings shall have the right to allow such walls or piers to be built of a less thickness than specified for brickwork, but in no case shall said walls or piers be less than three-quarters of the thickness provided for brick-work.

In all brick walls every sixth course shall be a heading course, except where walls are faced with brick in running bond, in which latter case every sixth course shall be bonded into the backing by cutting the course of the face brick and putting in diagonal headers behind the same, or by splitting the face brick in half and backing the same with a continuous row of headers. Where face brick is used of a different thickness from the brick used for backing, the courses of the ex-

terior and interior brickwork shall be brought to a level bed at intervals of not more than ten courses in height of the face brick, and the face brick shall be properly tied to the backing by a heading course of the face brick. All bearing walls faced with brick laid in running bond shall be 4 inches thicker than the walls are required to be under any section of this Code.

Sec. 29. *Ashlar.*—Stone used for the facing of any building, and known as ashlar, shall be not less than 4 inches thick.

Stone ashlar shall be anchored to the backing and the backing shall be of such thickness as to make the walls, independent of the ashlar, conform as to the thickness with the requirements of sections 31 and 32 of this Code, unless the ashlar be at least 8 inches thick and bonded into the backing, and then it may be counted as part of the thickness of the wall.

Iron ashlar plates used in imitation of stone ashlar on the face of a wall shall be backed up with the same thickness of brickwork as stone ashlar.

Sec. 30. *Mortar for Walls and Ashlar.*—All foundation-walls, isolated piers, parapet walls and chimneys above roofs shall be laid in cement mortar, but this shall not prohibit the use in cold weather of a small proportion of lime to prevent the mortar from freezing. All other walls built of brick or stone shall be laid in lime, cement, or lime and cement mortar mixed.

The backing up of all stone ashlar shall be laid up with cement mortar, or cement and lime mortar mixed, but the back of the ashlar may be pargeted with lime mortar to prevent discoloration of the stone.

Sec. 31. *Walls for Dwelling-houses.*—The expression "walls for dwelling-houses" shall be taken to mean and include this class walls for the following buildings:

Dwellings, asylums, apartment-houses, convents, club-houses, dormitories, hospitals, hotels, lodging-houses, tenements, parish buildings, schools, laboratories, studios.

The walls above the basement of dwelling-houses not over three stories and basement in height, nor more than 40 feet in height, and not over 20 feet in width, and not over 55 feet in depth, shall have side and party walls not less than 8 inches thick, and front and rear walls not less than 12 inches thick. All walls of dwellings exceeding 20 feet in width and not exceeding 40 feet in height shall be not less than 12 inches thick. All walls of dwellings 26 feet or less in width between bearing-walls which are hereafter erected or which may be altered to be used

for dwellings, and being over 40 feet in height and not over 50 feet in height, shall be not less than 12 inches thick above the foundation-wall. No wall shall be built having a 12-inch-thick portion measuring vertically more than 50 feet. If over 50 feet in height and not over 60 feet in height the wall shall be not less than 16 inches thick in the story next above the foundation-walls and from thence not less than 12 inches to the top. If over 60 feet in height, and not over 75 feet in height, the walls shall be not less than 16 inches thick above the foundation-walls to the height of 25 feet, or to the nearest tier of beams to that height, and from thence not less than 12 inches thick to the top. If over 75 feet in height, and not over 100 feet in height, the walls shall be not less than 20 inches thick above the foundation-walls to the height of 40 feet, or to the nearest tier of beams to that height, thence not less than 16 inches thick to the height of 75 feet, or to the nearest tier of beams to that height, and thence not less than 12 inches thick to the top. If over 100 feet in height, and not over 125 feet in height, the walls shall be not less than 24 inches thick above the foundation-walls to the height of 40 feet or to the nearest tier of beams to that height, thence not less than 20 inches thick to the height of 75 feet, or to the nearest tier of beams to that height, thence not less than 16 inches thick to the height of 110 feet, or to the nearest tier of beams to that height, and thence not less than 12 inches thick to the top. If over 125 feet in height and not over 150 feet in height, the walls shall be not less than 28 inches thick above the foundation-walls to the height of 30 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 65 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 100 feet, or to the nearest tier of beams to that height; thence not less than 16 inches thick to the height of 135 feet, or to the nearest tier of beams to that height, and thence not less than 12 inches thick to the top. If over 150 feet in height, each additional 30 feet in height or part thereof, next above the foundation-walls, shall be increased 4 inches in thickness, the upper 150 feet of wall remaining the same as specified for a wall of that height.

All non-fireproof dwelling-houses erected under this section, exceeding 26 feet in width, shall have brick fore-and-aft partition-walls. All non-bearing walls of buildings hereinbefore in

this section specified may be 4 inches less in thickness, provided however, that none are less than 12 inches thick, except as in this Code specified. 8-inch brick partition-walls may be built to support the beams in such building in which the distance between the main or bearing walls is not over 33 feet; if the distance between the main or bearing walls is over 33 feet the brick partition-wall shall be not less than 12 inches thick; provided, that no clear span is over 26 feet. No wall shall be built having any one thickness measuring vertically more than 50 feet. This section shall not be construed to prevent the use of iron or steel girders, or iron or steel girders and columns, or piers of masonry, for the support of the walls and ceilings over any room which has a clear span of more than 26 feet between walls, in such dwellings as are not constructed fireproof, nor to prohibit the use of iron or steel girders, or iron or steel girders and columns in place of brick walls in buildings which are to be used for dwellings when constructed fireproof. If the clear span is to be over 26 feet, then the bearing-walls shall be increased 4 inches in thickness for every 12½ feet or part thereof that said span is over 26 feet, or shall have, instead of the increased thickness, such piers or buttresses as, in the judgment of the Commissioner of Buildings having jurisdiction, may be necessary.

Whenever two or more dwelling-houses shall be constructed not over 12 feet 6 inches in width, and not over 50 feet in height, the alternating centre wall between any two such houses shall be of brick not less than 8 inches thick above the foundation-wall; and the ends of the floor-beams shall be so separated that 4 inches of brickwork will be between the beams where they rest on the said centre wall.

Sec. 32. *Walls for Warehouses.*—The expression "walls for warehouses" shall be taken to mean and include in this class walls for the following buildings:

Warehouses, stores, factories, mills, printing-houses, pumping-stations, refrigerating-houses, slaughter-houses, wheelwright-shops, cooperage-shops, breweries, light- and power-houses, sugar-refineries, office-buildings, stables, markets, railroad buildings, jails, police-stations, court-houses, observatories, foundries, machine-shops, public assembly buildings, armories, churches, theatres, libraries, museums. The walls of all warehouses 25 feet or less in width between walls or bearings shall be not less than 12 inches thick to the height of 40 feet above

the foundation-walls. If over 40 feet in height, and not over 60 feet in height, the walls shall be not less than 16 inches thick above the foundation-walls to the height of 40 feet, or to the nearest tier of beams to that height, and thence not less than 12 inches thick to the top. If over 60 feet in height, and not over 75 feet in height, the walls shall be not less than 20 inches thick above the foundation-walls to the height of 25 feet, or to the nearest tier of beams to that height, and thence not less than 16 inches thick to the top. If over 75 feet in height, and not over 100 feet in height, the walls shall be not less than 24 inches thick above the foundation-walls to the height of 40 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 75 feet, or to the nearest tier of beams to that height, and thence not less than 16 inches thick to the top. If over 100 feet in height, and not over 125 feet in height, the walls shall be not less than 28 inches thick above the foundation-walls to the height of 40 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 75 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 110 feet, or to the nearest tier of beams to that height, and thence not less than 16 inches thick to the top. If over 125 feet in height, and not over 150 feet the walls shall be not less than 32 inches thick above the foundation-walls to the height of 30 feet, or to the nearest tier of beams to that height; thence not less than 28 inches thick to the height of 65 feet, or to the nearest tier of beams to that height; thence not less than 24 inches thick to the height of 100 feet, or to the nearest tier of beams to that height; thence not less than 20 inches thick to the height of 135 feet, or to the nearest tier of beams to that height; and thence not less than 16 inches thick to the top. If over 150 feet in height, each additional 25 feet in height, or part thereof next above the foundation-walls shall be increased 4 inches in thickness, the upper 150 feet of wall remaining the same as specified for a wall of that height.

If there is to be a clear span of over 25 feet between the bearing-walls, such walls shall be 4 inches more in thickness than in this section specified, for every 12½ feet, or fraction thereof, that said walls are more than 25 feet apart, or shall have instead of the increased thickness such piers or buttresses as, in the judgment of the Commissioner of Buildings, may be necessary.

The walls of buildings of a public character shall be not less than in this Code specified for warehouses with such piers or buttresses, or supplemental columns of iron or steel, as, in the judgment of the Commissioner of Buildings having jurisdiction, may be necessary to make a safe and substantial building.

In all stores, warehouses, and factories over 25 feet in width between walls there shall be brick partition-walls, or girders supported on iron, steel, or wood columns, or piers of masonry.

In all stores, warehouses, or factories, in case iron, steel, or wood girders, supported by iron, steel, or wood columns, or piers of masonry, are used in place of brick partition-walls, the building may be 75 feet wide and 210 feet deep, when extending from street to street, or when otherwise located may cover an area of not more than 8000 superficial feet. When a building fronts on three streets it may be 105 feet wide and 210 feet deep, or if a corner building fronting on two streets it may cover an area of not more than 12,500 superficial feet; but in no case wider nor deeper, nor to cover a greater area, except in the case of fire-proof buildings. An area greater than herein stated may, considering location and purpose, be allowed by the Board of Buildings when the proposed building does not exceed three stories in height.

Sec. 33. *Increased Thicknesses of Walls for Buildings more than 105 feet in Depth.*—All buildings, not excepting dwellings that are over 105 feet in depth, without a cross-wall or proper piers or buttresses, shall have the side or bearing-walls increased in thickness 4 inches more than is specified in the respective sections of this Code for the thickness of walls for every 105 feet, or part thereof, that the said buildings are over 105 feet in depth.

Sec. 34. *Reduced Thickness for Interior Walls.*—In case the walls of any building are less than 25 feet apart, and less than 40 feet in depth, or there are cross-walls which intersect the walls, not more than 40 feet distant, or piers or buttresses built into the walls, the interior walls may be reduced in thickness in just proportion to the number of cross-walls, piers, or buttresses, and their nearness to each other; provided, however, that this clause shall not apply to walls below 60 feet in height, and that no such wall shall be less than 12 inches thick at the top, and gradually increased in thickness by set-offs to the bottom. The Commissioner of Buildings having jurisdiction is hereby authorized and empowered to decide (except

where herein otherwise provided for) how much the walls herein mentioned may be permitted to be reduced in thickness, according to the peculiar circumstances of each case, without endangering the strength and safety of the building.

Sec. 35. *One-story Brick Buildings.*—One-story structures not exceeding a height of 15 feet may be built with 8-inch walls when the bearing-walls are not more than 19 feet apart, and the length of the 8-inch bearing-walls does not exceed 55 feet. One-story and basement extensions may be built with 8-inch walls when not over 20 feet wide, 20 feet deep, and 20 feet high to dwellings.

Sec. 36. *Inclosure Walls for Skeleton Structures.*—Walls of brick built in between iron or steel columns, and supported wholly or in part on iron or steel girders, shall be not less than 12 inches thick for 75 feet of the uppermost height thereof, or to the nearest tier of beams to that measurement, in any building so constructed, and every lower section of 60 feet, or to the nearest tier of beams to such vertical measurement, or part thereof, shall have a thickness of 4 inches more than is required for the section next above it down to the tier of beams nearest to the curb-level; and thence downward, the thickness of walls shall increase in the ratio prescribed in section 26, this Code.

Sec. 37. *Curtain-walls.*—Curtain-walls built in between piers or iron or steel columns and not supported on steel or iron girders, shall be not less than 12 inches thick for 60 feet of the uppermost height thereof, or nearest tier of beams to that height, and increased 4 inches for every additional section of 60 feet or nearest tier of beams to that height.

Sec. 38. *Existing Party Walls.*—Walls heretofore built for or used as party walls, whose thickness at the time of their erection was in accordance with the requirements of the then existing laws, but which are not in accordance with the requirements of this Code, may be used, if in good condition, for the ordinary uses of party walls, provided the height of the same be not increased.

Sec. 39. *Lining Existing Walls.*—In case it is desired to increase the height of existing party or independent walls, which are less in thickness than required under this Code, the same shall be done by a lining of brickwork to form a combined thickness with the old wall of not less than 4 inches more than the thickness required for a new wall corresponding with the total height of the wall when so increased in height. The

said linings shall be supported on proper foundations and carried up to such height as the Commissioner of Buildings having jurisdiction may require. No lining shall be less than 8 inches in thickness, and all lining shall be laid up in cement mortar and thoroughly anchored to the old brick walls with suitable wrought-iron anchors, placed 2 feet apart and properly fastened or driven into the old walls in rows alternating vertically and horizontally with each other, the old walls being first cleaned of plaster or other coatings where any lining is to be built against the same. No rubble wall shall be lined except after inspection and approval by the Department.

Sec. 40. *Walls of Unfinished Buildings.*—Any building, the erection of which was commenced in accordance with specifications and plans submitted to and approved by the Department of Buildings prior to the passage of this Code, if properly constructed, and in safe condition, may be completed, or built upon in accordance with the requirements of law, as to thickness of walls, in force at the time when such specification and plans were approved.

Sec. 41. *Walls Tied, Anchored, and Braced.*—In no case shall any wall or walls of any building be carried up more than two stories in advance of any other wall, except by permission of the Commissioner of Buildings having jurisdiction, but this prohibition shall not include the inclosure walls for skeleton buildings. The front, rear, side and party walls shall be properly bonded together, or anchored to each other every 6 feet in their height by wrought-iron tie anchors, not less than $1\frac{1}{2}$ inches by $\frac{3}{8}$ inch in size, and not less than 24 inches in length. The side anchors shall be built into the side or party walls not less than 16 inches, and into the front and rear walls, so as to secure the front and rear walls to the side, or party walls, when not built and bonded together. All exterior piers shall be anchored to the beams or girders on the level of each tier. The walls and beams of every building, during the erection or alteration thereof, shall be strongly braced from the beams of each story, and when required, shall also be braced from the outside, until the building is inclosed. The roof tier of wood beams shall be safely anchored, with plank or joist, to the beams of the storly below until the building is inclosed.

Sec. 42. *Arches and Lintels.*—Openings for doors and windows in all buildings shall have good and sufficient arches of stone, brick, or terra-cotta, well built and keyed with good

and sufficient abutments, or lintels of stone, iron, or steel of sufficient strength, which shall have a bearing at each end of not less than 5 inches on the wall. On the inside of all openings in which lintels shall be less than the thickness of the wall to be supported, there shall be timber lintels, which shall rest at each end not more than 3 inches on any wall, which shall be chamfered at each end, and shall have a suitable arch turned over the timber lintel. Or the inside lintel may be of cast iron, or wrought iron or steel, and in such case stone blocks or cast-iron plates shall not be required at the ends where the lintel rests on the walls, provided the opening is not more than 6 feet in width.

All masonry arches shall be capable of sustaining the weight and pressure which they are designed to carry, and the stress at any point shall not exceed the working stress for the material used, as given in section 139 of this Code. Tie-rods shall be used where necessary to secure stability.

Sec. 43. *Parapet Walls.*—All exterior and division or party walls over 15 feet high, excepting where such walls are to be finished with cornices, gutters, or crown mouldings, shall have parapet walls not less than 8 inches in thickness and carried 2 feet above the roof, but for warehouses, factories, stores, and other buildings used for commercial or manufacturing purposes the parapet walls shall be not less than 12 inches in thickness and carried 3 feet above the roof, and all such walls shall be coped with stone, terra-cotta, or cast iron.

Sec. 44. *Hollow Walls.*—In all walls that are built hollow the same quantity of stone, brick, or concrete shall be used in their construction as if they were built solid, as in this Code provided, and no hollow wall shall be built unless the parts of same are connected by proper ties, either of brick, stone, or iron, placed not over 24 inches apart.

Sec. 45. *Hollow Bricks on Inside of Walls.*—The inside 4 inches of all walls may be built of hard-burnt hollow brick, properly tied and bonded into the walls, and of the dimension of ordinary bricks. Where hollow tile or porous terra-cotta blocks are used as lining or furring for walls, they shall not be included in the measurement of the thickness of such walls.

Sec. 46. *Recesses and Chases in Walls.*—Recesses for stairways or elevators may be left in the foundation- or cellar-walls of all buildings, but in no case shall the walls be of less thickness than the walls of the fourth story, unless reinforced by

additional piers with iron or steel girders, or iron or steel columns and girders, securely anchored to walls on each side. Recesses for alcoves and similar purposes shall have not less than 8 inches of brickwork at the back of such recesses, and such recesses shall be not more than 8 feet in width, and shall be arched over or spanned with iron or steel lintels, and not carried up higher than 18 inches below the bottom of the beams of the floor next above. No chase for water or other pipes shall be made in any pier, and in no wall more than one-third of its thickness. The chases around said pipe or pipes shall be filled up with solid masonry for the space of 1 foot at the top and bottom of each story. No horizontal recess or chase in any wall shall be allowed exceeding 4 feet in length without permission of the Commissioner of Buildings having jurisdiction. The aggregate area of recesses and chases in any wall shall not exceed one-fourth of the whole area of the face of the wall on any story, nor shall any such recess be made within a distance of 6 feet from any other recess in the same wall.

Sec. 47. *Furred Walls.*—In all walls furred with wood the brickwork between the ends of wood beams shall project the thickness of the furring beyond the inner face of the wall for the full depth of the beams.

Sec. 48. *Light and Vent Shafts*—In every building hereafter erected or altered, all the walls or partitions forming interior light or vent shafts, shall be built of brick, or such other fireproof materials as may be approved by the Commissioner of Buildings having jurisdiction. The walls of all light or vent shafts, whether exterior or interior, hereafter erected, shall be carried up not less than 3 feet above the level of the roof, and the brick walls coped as other parapet walls. Vent shafts to light interior bathrooms in private dwellings may be built of wood filled in solidly with brick or hard-burnt clay blocks, when extending through not more than one story in height, and carried not less than 2 feet above the roof, covered with a ventilating skylight of metal and glass.

Sec. 49. *Brick and Hollow-tile Partitions.*—Eight-inch brick and 6-inch and 4-inch hollow-tile partitions, of hard-burnt clay, or porous terra-cotta, may be built, not exceeding in their vertical portions a measurement of 50, 36, and 24 feet respectively, and in their horizontal measurement a length not exceeding 75 feet, unless strengthened by proper cross-walls, piers, or buttresses, or built in iron or steel framework. All such partitions shall

be carried on proper foundations, or on iron or steel girders, or on iron or steel girders and columns or piers of masonry.

Sec. 50. *Cellar Partitions in Residence Buildings.*—One line of fore-and-aft partitions in the cellar or lowest story, supporting stud partitions above, in all residence buildings over 20 feet between bearing-walls in the cellar or lowest story, hereafter erected, shall be constructed of brick, not less than 8 inches thick, or piers of brick with openings arched over below the under side of the first tier of beams, or girders of iron or steel and iron columns, or piers of masonry may be used; or if iron or steel floor beams spanning the distance between bearing-walls are used of adequate strength to support the stud partitions above in addition to the floor load to be sustained by the said iron or steel beams, then the fore-and-aft brick partition, or its equivalent, may be omitted.

Stud partitions which may be placed in the cellar or lowest story of any building shall have good solid stone or brick foundation-walls under the same, which shall be built up to the top of the floor-beams or sleepers, and the sills of said partitions shall be of locust or other suitable hard wood; but if the walls are built 5 inches higher of brick than the top of the floor-beams or sleepers, any wooden sill may be used on which the studs shall be set.

Sec. 51. *Main Stud Partitions.*—In residence buildings where fore-and-aft stud partitions rest directly over each other, they shall run down between the wood floor-beams and rest on the top plate of the partition below, and shall have the studding filled in solid between the uprights to the depth of the floor-beams with suitable incombustible materials.

Sec. 52. *Timber in Walls Prohibited.*—No timber shall be used in any wall of any building where stone, brick, or iron is commonly used, except inside lintels, as herein provided, and brace blocks not more than 8 inches in length.

Pointing.—Fig. 122 shows different styles of pointing used in face brickwork, that shown at *I* being the most common, or what is known as the struck joint; it is made with the point of the trowel, using the lower course of brick to rest the trowel on, and the top course as a guide for drawing the trowel along.

Some architects object to this style of joint, claiming the small projection on the lower course forms a table to catch the water, and preferring that shown at *K*, which is just the reverse of that at *I*. The author has used both, and for looks prefers

that shown at *I*, for this reason: A person standing on the ground and looking up at a wall with joints struck as shown at *K*, the eye will catch the little projection on every course of brick and cause the wall to look rough, but with the method

FIG. 122.

shown at *I*, the projections cannot be seen and the wall looks perfectly smooth to the eye.

One point the superintendent must watch in striking the joints is to see that the mason holds his trowel at the right angle and does not strike the joint as shown at *J*. The method shown at *A* is much used in press-brick work, being a combination of the methods shown at *I* and *K*. The joint shown at *D* is

made by using an iron rod the thickness of the joint; this is laid on the face edge of the brick already laid and the mortar spread out to it; after the bricks are laid and the mortar has sufficiently hardened the rod is taken out and the mortar smoothed, if necessary, with a tool. It takes several rods, as the mason will lay up several courses before the mortar is hard enough to permit the rod to be taken out. The rest of the joints shown are made with a jointing tool of the desired shape. The pointing of brickwork is done as the walls are built, and the superintendent must pay attention to see that it is done correctly as the work progresses.

EFFLORESCENCE.—When the face of some walls become wet or damp they will be covered with a sort of white efflorescence; it is in some cases a nitrate or carbonate of potash, more frequently a carbonate or sulphate of soda. There is no way to prevent this unless by coating the bricks with some preparation to render them water- and moisture-proof.

Estimating Bricklayers' Work.—Brickwork is estimated at the rate of a brick and a half thick. Therefore if a wall be more or less than this standard of thickness, it must be reduced to it as follows:

Rule.—Multiply the superficial contents of the wall by the number of half bricks in the thickness and one-third of that product will be the contents required.

Example.—How many bricks will it require to build a house 30 feet square, 20 feet high, and 12 inches thick, above which is a triangular gable rising 12 feet and 8 inches thick?

30×6 = 180 = 1 gable end
30×6 = 180 = 1 gable end

360×15 = ... 5,400
30+30 = 60 = two side walls
28+28 = 56 = two end walls

116
20 = height

2320×22½ = ... 52,200

57,600 (*Ans.*)

One barrel lime will lay 1000 to 1200 bricks.

One man with one tender will lay 1800 to 2000 bricks per day.

One thousand bricks closely stacked occupy 56 cubic feet.

One thousand old bricks cleaned and loosely stacked occupy about 70 cubic feet.

Six hundred bricks, 1 cubic yard in wall.

TABLE OF NUMBER OF BRICKS REQUIRED IN A WALL PER SQUARE FOOT OF FACE OF WALL.

4 inches	7½	24 inches	45
8 "	15	28 "	52½
12 "	22½	32 "	60
16 "	30	36 "	67½
20 "	37½	40 "	75

TABLE TO FIND THE NUMBER OF BRICKS IN ANY WALL.

Superficial Feet of Wall.	Number of Bricks to Thickness of Wall.					
	4-inch.	8-inch.	12-inch.	16-inch.	20-inch.	24-inch.
1	7½	15	23	30	38	45
2	15	30	45	60	75	90
3	23	45	68	90	113	135
4	30	60	90	120	150	180
5	38	75	113	150	188	225
6	45	90	135	180	225	270
7	53	105	158	210	263	315
8	60	120	180	240	300	300
9	68	135	203	270	338	405
10	75	150	225	300	375	450
20	150	300	450	600	750	900
30	225	450	675	900	1,125	1,350
40	300	600	900	1,200	1,500	1,800
50	375	750	1,125	1,500	1,875	2,250
60	450	900	1,350	1,800	2,250	2,700
70	525	1,050	1,575	2,100	2,625	3,150
80	600	1,200	1,800	2,400	3,000	3,600
90	675	1,350	2,025	2,700	3,375	4,050
100	750	1,500	2,250	3,000	3,750	4,500
200	1,500	3,000	4,500	6,000	7,500	9,000
300	2,250	4,500	6,750	9,000	11,250	13,500
400	3,000	6,000	9,000	12,000	15,000	18,000
500	3,750	7,500	11,250	15,000	18,750	22,500
600	4,500	9,000	13,500	18,000	22,500	27,000
700	5,250	10,500	15,750	21,000	26,250	31,500
800	6,000	12,000	18,000	24,000	30,000	36,000
900	6,750	13,500	20,250	27,000	33,750	40,500
1,000	7,500	15,000	22,500	30,000	37,500	45,000

Example.—Find the number of bricks in a wall 8 inches thick, 5 feet high, and 10 feet long; five multiplied by ten equals 50 feet of wall 8 inches thick. Under 8 inches and opposite 50 you will find 750, the number of bricks in the wall.

The above tables are based on the usual sizes of Eastern brick; Western brick are made some larger and will take a slight percentage less than in the above tables.

Paving, etc.—As a guide for street-paving, etc., the following specifications are given which form a good guide for such work:

SPECIFICATIONS.

CITY OF CHICAGO, BOARD OF LOCAL IMPROVEMENTS.

COMBINED CURB AND GUTTER. STREET-PAVING. PORTLAND-CEMENT FOUNDATION. WEARING SURFACE, EITHER BRICK OR ASPHALT.

COMBINED CURB AND GUTTER.—In making the combined curb and gutter Portland cement shall be used and ordinarily will be subjected to the following inspection and tests:

Fineness.—It shall be so ground that nine-two (92) per cent will pass through a standard No. 100 sieve having 10,000 meshes per square inch.

Soundness.—It shall meet the requirement of the "boiling" test.

Setting.—The cement when mixed with twenty (20) per cent of water, by measure, shall take initial set in not less than forty-five (45) minutes.

Strength.—Briquettes one (1″) inch square in section shall develop the following ultimate tensile strength:

Neat—one day in air and 6 days in water, 400 pounds.

One (1) part cement to two (2) parts fine granite screenings—one day in air and 6 days in water, 200 pounds; and shall show a gradual increase in strength of fifteen (15) per cent at the end of twenty-eight (28) days.

Samples of cements which it is proposed to use in the work shall be submitted to the Board of Local Improvements in such quantities and such time and place as to make all the required tests.

The Board of Local Improvements reserves the right to reject without recourse any cement which is not satisfactory, whether for reasons mentioned in these specifications or for any good and sufficient cause.

All cement to be used in the combined curb and gutter must be delivered on the work in approved packages bearing the name, brand, or stamp of the manufacturer. It shall be thoroughly protected from the weather until used, in such manner as may be directed.

The granite screenings used in making the concrete shall be clean, dry, free from, dust, loam, and dirt, and when delivered on the street shall be deposited on flooring and kept clean until used.

The crushed granite shall be clean, free from dust and dirt, broken so as to measure not more than one (1″) inch in any dimension, and when delivered on the street shall be deposited on a flooring and kept clean until used.

The granite concrete combined curb and gutter shall be constructed at the established grade and in a continuous line on each side of the street........(..′) feet from and parallel with the centre line thereof, except at all intersections of streets and alleys, where it shall be returned to the street line, and at such intersections there shall be formed the necessary circular stones built to such radii as the engineer may direct. All grades and lines will be given by the engineer. The combined curb and gutter shall rest on a foundation of cinders which must be six (6″) inches in thickness after being thoroughly flooded and compactly rammed to an even surface.

The curb and gutter shall be made of concrete formed by intimately mixing one (1) part of cement with two (2) parts of fine granite screenings; to this mixture shall be added four (4) parts of crushed granite and the whole thoroughly mixed together, after which just sufficient water to wet the mass shall be added, so that when it is rammed in place a film of moisture shall appear on top. All exposed surfaces shall be covered with a finishing coat of mortar three-eighths ($\frac{3}{8}$″) inch in thickness, composed of one (1) part of the cement thoroughly mixed with one and one-half ($1\frac{1}{2}$) parts of the fine granite screenings. Before the concrete sets, the curb and gutter shall be cut into sections not exceeding six (6′) feet in length.

The gutter flag must be eighteen (18″) inches wide and five (5″) inches thick; the curb must be seven (7″) inches thick throughout, except at the upper face corner, which is to be rounded to a radius of one and one-half ($1\frac{1}{2}$″) inches. The height of the curve above the gutter flags will be of varying dimensions, averaging not less than.......(..″) inches.

The contractor or contractors shall build without extra charge all "inlets" necessary to properly connect the combined curb and gutter with the catch-basins and such steps on the gutter flags at the crossings as the engineer may direct.

The curb and gutter shall be back-filled to the top, and filling

at that point shall be four (4′) feet wide and shall have a slope of one and one-half ($1\frac{1}{2}$) horizontal to one (1) vertical. The full quantity of filling shall be put in front and back of each section of curb and gutter as it is built, and must be thoroughly rammed with a proper rammer at the same time so that the curb and gutter will be firmly held in place.

Concrete Foundation.—After the sub-grade is prepared a foundation of Portland-cement concrete to a uniform thickness of six (6″) inches shall be laid.

Cement.—In making the concrete, Portland cement shall pass same specifications as for cement used in curb and gutter work.

Sand.—The sand used in making the concrete shall be clean, dry, free from dust, loam, and dirt, of sizes ranging from one-eighth ($\frac{1}{8}$″) inch down to the finest, and in such proportion that the voids as determined by saturation shall not exceed thirty-three (33) per cent of the entire volume, and it shall weigh not less than one hundred (100) pounds per cubic foot.

No wind-drifted sand shall be used.

The sand when delivered on the street shall be deposited on flooring and kept clean until used.

Crushed Stone.—The crushed stone used in making the concrete shall be of the best quality of limestone, clean, free from dirt, broken so as to measure not more than two (2″) inches and not less than one (1″) inch in any dimension.

The stone when delivered on the street shall be deposited on flooring and kept clean until used.

Mixing and Laying of Concrete.—The concrete shall be mixed on movable tight iron platforms of such size as shall accommodate the manipulations hereinafter specified.

The cement, sand, and stone shall be mixed in the following proportions: One (1) part of cement, three (3) parts of sand, and seven (7) parts of crushed stone. The sand and cement shall be thoroughly mixed, dry, to which sufficient water shall be added and then made into a stiff mortar. The crushed stone shall then be immediately incorporated in the mortar and the mass thoroughly mixed, adding water from time to time as the mixing progresses, until each particle of stone is covered with mortar.

The concrete shall be removed from the platform with shovels and deposited in a layer on the roadway in such quantities that after being rammed in place it shall be of the required thickness

and the upper surface shall be true and smooth and . . . . . (. . ″) inches below and parallel with the top of the finished pavement.

During the progress of the *work the sub-grade must be kept moist.*

The concrete shall be sprinkled so as to prevent checking in hot weather, and shall be protected from injury at all times, and shall lay at least seven days before being covered with the wearing surface, or a longer time if deemed necessary.

Sand Cushion.—Upon the concrete foundation shall be spread a layer of sand in such quantity as to insure, when compacted, a uniform thickness of one (1″) inch.

On surfacing said layer of sand the contractor or contractors shall use such guides and templets as the engineer may direct.

Wearing Surface.—Upon the layer of sand as above specified shall be placed the brick of such quality and in such manner as hereinafter specified.

Quality of Bricks.—The brick to be used shall be of the best quality of vitrified paving brick. Salt-glazed bricks will not be received.

The dimensions of the brick used shall be the same throughout the entire work in any particular case, and shall be not less than eight (8″) inches in length, four (4″) inches in depth, and two and one-half ($2\frac{1}{2}$″) inches in thickness, with rounded edges to a radius of one-quarter ($\frac{1}{4}$″) of an inch.

Said brick shall be of a kind known as repressed vitrified paving brick and shall be repressed to the extent that the maximum amount of material is forced into them. They shall be free from lime and other impurities, shall be as nearly uniform in every respect as possible, shall be burned so as to secure the maximum hardness, so annealed as to reach the ultimate degree of toughness, and thoroughly vitrified so as to make a homogeneous mass.

The bricks shall be free from all laminations caused by the process of manufacture, and free from fire-cracks or checks of more than superficial character or extent.

Any firm, person, or corporation bidding for the work to be done shall furnish specimen brick, which shall be submitted to a "water-absorption" test, and if such brick show a water absorption exceeding three (3) per cent of their weight when dry, the bid of the person, firm, or corporation so furnishing the same shall be rejected. Such "water-absorption" test shall be made by the Board of Local Improvements of the City of

Chicago, in the following manner, to wit: Not less than three (3) bricks shall be broken across, thoroughly dried, and then immersed in water for seventy-two (72) hours. The absorption shall then be determined by the difference between the weight dry and the weight at the expiration of said seventy-two (72) hours.

Twenty or more specimen bricks shall also be furnished by each bidder for submission to the "abrasion" test by the Board of Local Improvements. Such test shall be made in the following manner, to wit: Such specimen brick or a sufficient number to fill 15 per cent of the volume of the rattler shall be submitted to a test for one hour in the machine known as the "rattler," which shall measure twenty (20″) inches in length and twenty-eight (28″) inches in diameter, inside measurement, and shall be revolved at the rate of thirty (30) revolutions per minute If the loss of weight by abrasion during such test shall exceed twenty (20) per cent of the original weight of the brick tested, then such bid shall be rejected.

All brick shall have a specific gravity of not less than two and one-tenth ($2^1/_{10}$), as determined by the formula specific gravity equals $\frac{W}{W'W''}$; where W equals weight of brick dry, W' equals weight of brick after being immersed in water for seventy-two (72) hours, and W'' equals weight of brick in water.

All brick used must be equal in every respect to the specimen submitted by the bidders to the Board of Local Improvements for test.

How Laid.—All brick shall be delivered on the work in barrows, and in no case will teams be allowed on the street before the wearing surface is rolled.

Broken bricks can only be used to break joints in starting courses and in making closures, but in no case shall less than half a brick be used.

The bricks shall be laid on edge, close together, in straight lines across the roadway, between gutters, and at right angles to the curbs and perpendicular to the grade of the street. Gutters shall be constructed as directed by the engineer.

The joints shall be broken by a lap of not less than three (3″) inches.

On intersections and junctions of lateral streets the bricks shall be laid at an angle of forty-five (45°) degrees with the line of the street unless otherwise ordered by the engineer.

The bricks when set shall be rolled with a roller weighing not less than five (5) tons until the bricks are well settled and made firm. Or, if the engineer shall direct, the bricks, when set, shall be thoroughly rammed two or more times, the ramming to be done under a flatter, with a paving rammer weighing not less than thirty (30) pounds, the iron of the rammer face in no case to come in contact with the pavement.

After rolling and ramming, all broken brick found in the pavement must at once be removed and replaced by sound and perfect brick.

Pitching or Grouting and Top-dressing. — When the bricks are thoroughly bedded, the surface of the pavement must be true for grade and crown. The surface of the pavement shall then be swept clean, and the joints or spaces between the brick shall be completely filled with a paving pitch which is the direct result of the distillation of "straight-run" coal-tar, and of such quality and consistency as shall be approved by the Board of Local Improvements. The pitch must be used at a temperature of not less than 280 degrees Fahrenheit.

When the brick are thoroughly bedded, the surface of the pavement must be true for grade and crown. The surface of the pavement shall then be swept clean, and the joints or spaces between the bricks shall be filled with a cement grout filler composed of limestone 65 per cent, furnace slag 25 per cent, and potters' clay 10 per cent, to be made as follows: The above materials in the proportions stated shall be mixed together and ground into an impalpable powder and then burned in kilns until reduced to clinker, after which it shall again be ground into an impalpable powder. Equal portions of said grout and clean, sharp sand shall then be thoroughly mixed, and sufficient water added to bring the mixture to such a consistency as will allow it to run to the bottom of the joints between the brick. After said joints are filled to the top, the surface shall be finished off smoothly with steel brooms.

After the spaces between the brick have been filled with the pitch or grout as above specified, the surface of the pavement shall then receive a one-half (½″) inch dressing of sand, evenly spread over the whole surface.

Where cement grout is used as a filler the pavement must be kept clear of traffic for a period of four (4) days—or as much longer as the engineer may direct—after the application thereof.

Asphaltic Cement.—The asphaltic cement hereinafter speci-

fied shall be made of refined Trinidad Lake asphalt, obtained from the island of Trinidad, or of an asphalt of equal quality for paving purposes, and heavy petroleum-oil. The oil shall be mixed with the asphalt in such proportions as are suitable to the character of the asphalt used.

BINDER COURSE.—Upon the concrete foundation as above specified shall be laid a "binder" course, composed of clean broken limestone of a size known as "small concrete," and asphaltic cement. The stone shall be heated and thoroughly mixed with asphaltic cement in the proportion of fifteen (15) gallons of asphaltic cement to one (1) cubic yard of stone; the mixing shall be continued until each particle of stone is thoroughly coated with the asphaltic cement. This binder shall be spread on the base above described, and, while in a hot and plastic condition, shall be rolled with a five (5) ton steam-roller until it has a uniform thickness of one and one-half ($1\frac{1}{2}''$) inches. The upper surface shall be parallel with and two ($2''$) inches below the final surface of the pavement.

Binder that has been burned or has become chilled shall be removed from the line of the work.

WEARING SURFACE.—Upon this binder course shall be laid a wearing surface, which shall be composed of asphaltic cement seventeen (17) parts, sand seventy-three (73) parts, and pulverized carbonate of lime ten (10) parts. The sand and asphaltic cement shall be heated separately to a temperature of three-hundred (300°) degrees Fahrenheit. The pulverized carbonate of lime shall be mixed with the sand, and these ingredients then mixed with the asphaltic cement at the above temperature, in an apparatus which shall effect a perfect mixture.

The mixture at a temperature of not less than two hundred and fifty (250°) degrees Fahrenheit shall then be carefully spread by means of hot iron rakes in such a manner as to give a uniform and regular grade, and on such a depth that after having received its ultimate compression it will have a thickness of two ($2''$) inches. The surface shall be compressed by rollers, after which a small amount of hydraulic cement shall be swept over it, and it shall then be thoroughly compressed by a fifteen (15) ton steam-roller, the rolling being continued as long as it makes an impression on the surface.

Where necessary to make the gutters impervious to water, a width of twelve ($12''$) inches next to the curb shall be coated

with hot pure asphalt and smoothed with hot smoothing-irons in order to saturate the pavement with excess of asphalt.

Headers.—At the end of each intersecting street and alley wing there shall be placed a "header," extending from curb to curb, and so dressed as to conform to the crown of the pavement. The "header" shall be constructed of three by twelve (3″×12″) inch oak plank, properly supported by six (6″) inch split cedar posts, three (3′) feet in length, firmly set in the ground and spaced not more than five (5′) feet apart.

All "headers" shall be constructed by the contractor or contractors without extra charge.

Crosswalks.—Unless otherwise directed by the engineer there shall be formed in the pavement four (4) crosswalks at each street intersection, three (3) at each half intersection, and one (1) near the middle of each long block. A gutter nine (9″) inches in the clear width shall be constructed at the ends of the crosswalks by setting sandstone curbing in the roadway nine (9″) inches from and parallel with the curb line. The sandstone curbing must be four (4″) inches thick and twenty-four (24″) inches deep, and the length of the curbing shall be within two (2′) feet of the width of the abutting sidewalk space; provided, however, that the minimum length of said curbing shall be six (6′) feet.

The crosswalks, gutters, and their appurtenances shall be formed and constructed where and as directed by the engineer, and without extra cost over and above the price paid per square yard for the pavement.

PART III.

LIME, SAND, CEMENT, MORTAR, AND CONCRETE. CONCRETE CONSTRUCTION. FIRE-PROOF FLOOR CONSTRUCTION, PARTITIONS, ETC. ARCHITECTURAL TERRA-COTTA. FIRE-PROOF CONSTRUCTION AND FIRE PROTECTION OF BUILDINGS.

Lime, Sand, and Cement.—Mortar is one of the principal materials used in construction, and upon which the strength and stability of the structure depends to a great extent; hence the different materials and proportions used in making the mortar must receive particular attention from the superintendent. He must be so familiar with the different materials used that he will be able to judge the quality of them so as to determine any worthless material and reject it at once.

SAND.—Sand, which enters largely into the composition of all mortars, should be sharp and angular and comparatively free from any dirt or loam. Recent experiments have shown that a slight percentage of clay in the sand used for cement mortar does not affect its strength, but there should not be more than 5 per cent of clay in the sand. For rough stone or common brick work the sand should be coarse, but for "press" brick and setting ashlar it should be fine, so as to get a close joint. Marble dust is often used in place of sand where a close joint is desired in the work.

By taking a small amount of sand and spreading it over the hand or examining it with a magnifying-glass the superintendent can readily determine its quality.

When ocean sand is used for plastering or any work where the salt is liable to come to the surface and show, it should be thoroughly washed.

For concrete or any rough work, the salt does not affect it.

Lime. — Lime is obtained by burning limestone. When carbonate of lime is calcined the carbonic acid is thrown off and lime is obtained. It is then known as caustic lime or quicklime; if it then be mixed with water it will throw out great heat, swell to several times its original bulk, and finally falls to a powder. In this state it is known as slaked or a hydrate of lime.

The quality of lime depends on the composition of the limestone from which it is made. Those stones which are nearly pure carbonate of lime make the best lime, while those which contain much impurities, such as silica, clay, magnesia, and alkalies, make the poorest lime according to the amount of impurities contained.

Good lime should be free from cinders or unburned stone, and not contain a large per cent of impurities; over 10 per cent of impurities makes poor lime and it should be rejected.

Lime should be in large hard pieces and contain little dust. When wet with water it should slake readily into a smooth, fine paste or putty. The lime should slake by simply immersing it it the water, although stirring it will hasten it somewhat.

The superintendent should see that the lime used is freshly burned and has not been exposed to the air, which will cause it to "air slake" and make it unfit for use; he should also see that proper provisions have been made to keep and protect the lime at the work, for lime exposed to a damp atmosphere for a day will absorb dampness enough to cause it to slake.

What One Barrel of Lime Will Do.

1 barrel of lime will make $2\frac{3}{4}$ barrels of paste.
1 " " " " lay 3 perch of stone rubble.
1 " " " " " 1000 to 1200 bricks.
1 " " " " plaster 28 yards of 3-coat work.
1 " " " " " 40 " " 2- " "
1 " " " equals 3 bushels of 80 pounds each.

Hydraulic Lime.—Hydraulic lime is made from calcareous rock containing 12 to 30 per cent of silica, alumina, iron, and

magnesia; when calcined at a low temperature it will slake and will set and harden in water in from one to ten days to five or six months, depending on the amount of silica and alumina contained. Hydraulic lime is not used much in this country, as natural cement takes its place. The following is an average of French hydraulic lime:

Silica	22.0	per cent
Alumina	2.0	"
Oxide of iron	1.0	"
Lime	63.0	"
Magnesia	1.5	"
Sulphuric acid	0.5	"
Water	10.0	"
	100.0	per cent

Cements.—Natural cements are generally called Rosendale cement, from the name of the town in New York where it was first made in this country. It is made from a natural rock containing about 60 per cent of lime and magnesia to about 40 per cent of silica and alumina, with a little iron or potash. This cement sets and attains its limit of strength much quicker than Portland, and is used where extreme strength is not necessary. Portland cement, because the price is becoming cheaper than in former days, is now fast taking the place of Rosendale cement.

Rosendale cement is usually a dark brown; a light color indicates an inferior cement.

Weight and Chemical Analysis.—*Weight.*—The average weight of Louisville or Rosendale cement is as follows:

1 cubic foot, loose	55½	pounds.
1 cubic foot, packed	74	"

Therefore a barrel of 265 pounds contains 4.77 cubic feet of loose cement and 3.58 cubic feet of packed cement.

Louisville cement is shipped in three kinds of packages: barrels, weighing 285 pounds gross; paper bags, 82 pounds each; and jute sacks, weighing 133 pounds each.

Chemical Analysis.—The following is a characteristic analysis of Louisville or Rosendale cement:

Silica	26.40	per cent
Alumina	6.28	"
Iron oxide	1.00	"
Lime	45.22	"
Magnesia	9.00	"
Potash and soda	4.24	"
Sulphate lime	0.00	"
Carbonic acid, water, and loss	7.86	"
	100.00	per cent

The following specifications for natural cements have been prepared and are used by the United States Engineer Department;

SPECIFICATIONS FOR NATURAL CEMENT.

(1) The cement shall be a freshly packed natural or Rosendale, dry and free from lumps. By natural cement is meant one made by calcining natural rock at a heat below incipient fusion and grinding the product to powder.

(2) The cement shall be put up in strong, sound barrels, well lined with paper so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labelled with the name of the brand and of the manufacturer.

Any package broken or containing damaged cement may be rejected or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor:

No cement will be allowed to be used except established brands of high-grade natural cement which have been in successful use under similar climatic conditions to those of the proposed work.)

(5) The average net weight per barrel shall not be less than 300 pounds. (West of the Allegheny Mountains this may be 265 pounds.) . . . Sacks of cement shall have the same weight as 1 barrel. If the average net weight, as determined by test weighings, is found to be below 300 pounds (265) per barrel, the cement may be rejected, or, at the option of the engineer officer in charge, the contractor may be required to supply free of cost to the United States an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, time of setting, and tensile strength of the cement.

(7) FINENESS.—At least 80 per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) TIME OF SETTING.—The cement shall not acquire its initial set in less than twenty minutes and must have acquired its final set in four hours.

(9) The time of setting is to be determined from a pat of neat cement mixed for five minutes with 30 per cent of water by weight and kept under a wet cloth until finally set. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to weigh 1 pound.

(10) TENSILE STRENGTH.—Briquettes made of neat cement shall develop the following tensile strengths per square inch, after having been kept in air for twenty-four hours under a wet cloth and the balance of the time in water:

At the end of seven days, 90 pounds; at the end of twenty-eight days, 200 pounds.

Briquettes made of one part cement and one part standard sand by weight shall develop the following tensile strengths per square inch:

After seven days, 60 pounds; after twenty-eight days, 150 pounds.

(11) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(12) The neat cement for briquettes shall be mixed with 30

per cent of water by weight, and the sand and cement with 17 per cent of water by weight. After being thoroughly mixed and worked for five minutes the cement or mortar is to be placed in the briquette mould in four equal layers, each of which is to be rammed and compressed by thirty blows of a soft brass or copper rammer three-fourths of an inch in diameter (or seven-tenths of an inch square with rounded corners), weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. Upon completion of ramming the surplus cement shall be struck off and the layer smoothed with a trowel held nearly horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mould.

(13) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of the bids. Any cement showing, by sample, higher tests than those given must maintain the average so shown in subsequent deliveries.

(14) A cement may be rejected which fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer may, if he deems it to the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner above specified. All expenses of such tests shall be paid by the contractor, and all such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

Portland Cement.—Portland cement is what is known as a tri-calcic cement and is composed of lime, silica, alumina, iron oxide, and magnesia artificially blended together into a scientifically correct mixture and burned at a white heat. The process varies greatly with the character of the raw materials used.

By the heat of the kiln the silica, lime, alumina, and oxide of iron become silicate of lime and alumina, and aluminate of lime and ferrite of lime. If the composition of these compounds is brought about in the right proportions in the molecule and in the mass, their nature is to crystallize when wet with water, and then harden till they become as rocks

When any lime leaves the kiln uncombined and is not changed to hydrate of lime, or carbonate of lime by exposure to the air, the uncombined lime will act as a deleterious ingredient, and is the cause of the swelling of cement in barrels and the checking and blowing found in finished cement-work; if the cement contains any of this uncombined lime it will generally show in the tests made for soundness or expansion.

Nearly all the Portland cement made in this country is produced artificially. The name "Portland" is given the cement on account of its color when hardened, which resembles the color of a stone found on the Isle of Portland, off the coast of England.

The quality of Portland cement depends on the raw materials used, their proportion, and fineness to which it is ground. Portland cement sets much slower than the natural cements and requires a much longer time to reach its limit of strength, but attains a much greater strength than the natural cement.

The color of Portland cement is a dark bluish or drab color. It should weigh at least 375 pounds per barrel and 4 sacks should equal a barrel. A cement which is lighter in weight than this is liable to be poor.

CHEMICAL COMPOSITION.—The ordinary composition of a good Portland cement varies as follows:

Lime	from 60 to 64	per cent
Silica	from 20 to 24	"
Alumina and iron oxide	from 8 to 12	"
Magnesia	from 1 to 3½	"
Alkalies	from trace to 2	"
Sulphuric acid	from 1 to 2	"

Cement containing over 3½ per cent of magnesia and 2 per cent of sulphuric acid should be avoided.

The manufacturers of Portland cement will usually sell their cement under the following guarantee:

1st. The cement will stand a minimum tensile strain of 600 pounds to the square-inch section of neat briquettes kept one day in air and six days in water. 2d. The cement will stand a minimum tensile strain of 175 pounds per square-inch section, 3 parts of sand and 1 part of cement, the briquettes kept one day in air and six days in water, standard crushed quartz used in testing. 3d. The cement will stand what is known as the

boiling test. 4th. 85 per cent of this cement will pass through a No. 200 sieve. 96 per cent will pass through a No. 100 sieve. All of the barrel cement will be put up in tight packages of great strength and uniformity. The bag cement will be put up in cotton bags of superior quality, and all the weights are strictly guaranteed.

The following are the specifications used by the United States Engineering Department for Portland cement·

SPECIFICATIONS FOR AMERICAN PORTLAND CEMENT.

(1) The cement shall be an American Portland, dry and free from lumps. By a Portland cement is meant the puctrod obtained from the heating or calcining up to incipient fusion of intimate mixtures, either natural or artificial, of argillaceous with calcareous substances, the calcined product to contain at least 1.7 times as much of lime, by weight, as of the materials which give the lime its hydraulic properties, and to be finely pulverized after said calcination, and thereafter additions or substitutions for the purpose only of regulating certain properties of technical importance to be allowable to not exceeding 2 per cent of the calcined product.

(2) The cement shall be put up in strong, sound barrels well lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labelled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected or accepted as a fractional package, at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not established itself as a high-grade Portland cement and has not for three years or more given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed.

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor:

No cement will be allowed to be used except established

brands of high-grade Portland cement which have been made by the same mill and in successful use under similar climatic conditions to those of the proposed work for at least three years.)

(5) The average weight per barrel shall not be less than 375 pounds net. Four sacks shall contain one barrel of cement. If the weight, as determined by test weighings, is found to be below 375 pounds per barrel, the cement may be rejected, or, at the option of the engineer officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, specific gravity, soundness, time of setting, and tensile strength of the cement.

(7) Fineness.—Ninety-two per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) Specific Gravity.—The specific gravity of the cement, as determined from a sample which has been carefully dried, shall be between 3.10 and 3.25.

(9) Soundness.—To test the soundness of the cement, at least two pats of neat cement, as taken from the package, mixed for five minutes with about 20 per cent of water by weight, shall be made on glass, each pat about 3 inches in diameter and one-half inch thick at the centre, tapering thence to a thin edge. The pats are to be kept under a wet cloth until finally set, when one is to be placed in fresh water for twenty-eight days. The second pat will be placed in water which will be raised to the boiling-point for six hours, then allowed to cool. Neither should show distortion or cracks. The boiling test may or may not reject at the option of the engineer officer in charge.

(10) Time of Setting.—The cement shall not acquire its initial set in less than forty-five minutes and must have acquired its final set in ten hours.

(The following paragraph will be substituted for the above in case a quick-setting cement is desired:

The cement shall not acquire its initial set in less than twenty nor more than thirty minutes, and must have acquired its final set in not less than forty-five minutes nor in more than two and one-half hours.)

The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being

appreciably indented, a wire one-twelfth inch in diameter loaded to weigh one-fourth pound. The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to weigh 1 pound.

(11) Tensile Strength.—Briquettes made of neat cement, after being kept in air for twenty-four hours under a wet cloth and the balance of the time in water, shall develop tensile strength per square inch as follows:

After seven days, 450 pounds; after twenty-eight days, 540 pounds.

Briquettes made of 1 part cement and 3 parts standard sand, by weight, shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; after twenty-eight days, 220 pounds.

(In case quick-setting cement is desired, the following tensile strengths shall be substituted for the above:

Neat briquettes: After seven days, 400 pounds; after twenty-eight days, 480 pounds.

Briquettes of 1 part cement to 3 parts standard sand: After seven days, 120 pounds; after twenty-eight days, 180 pounds.)

(12) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(13) When making briquettes well-dried cement and sand will be used; neat cement will be mixed with 20 per cent of water by weight, and sand and cement with 12½ per cent of water by weight. After being thoroughly mixed and worked for five minutes, the cement or mortar will be placed in the briquette mould in four equal layers, and each layer rammed and compressed by thirty blows of a soft brass or copper rammer three-quarters of an inch in diameter (or seven-tenths of an inch square, with rounded corners), weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. When the ramming has been completed, the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mould.

(14) The above are to be considered the minimum requirements. Unless a cement has been recently used on work

under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subsequent shipments must come up to those found with the sample.

(15) A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer in charge may, if he deem it to the interest of the United States, have any or all of the tests made or repeated at some recognized standard testing laboratory in the manner herein specified. All expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

Puzzolan Cement.—This was originally an imported cement, made from a natural burned material of volcanic origin, but the slag cements now being made are really Puzzolan cement and should be classed under that head.

The so-called slag cement is the product obtained by pulverizing, without calcination, a mixture of granulated basic blast-furnace slag and slaked lime. This product, though in reality a member of the class of Puzzolanic cements, is usually marketed as "Portland cement," in spite of the fact that it differs from a true Portland cement in method of manufacture, ultimate and rational composition and properties.

Some recent tests made with slag cement in the municipal laboratory at Vienna, gave the following results: The mortar was mixed one to three. After seven days hardening, tensile strength, 383 pounds per square inch; strength of compression, 3880 pounds per square inch. After twenty-eight days hardening, tensile strength, 551 pounds per square inch; strength of compression, 5411 pounds per square inch.

The following regarding Puzzolan or slag cement is taken from the professional papers of the United States Engineer Corps:

SLAG CEMENT.—This term is applied to cement made by intimately mixing by grinding together granulated blast-furnace slag of a certain quality and slaked lime, without calcination subsequent to the mixing. This is the only cement of the Puzzolan class to be found in our markets (often branded as Portland), and as true Portland cement is now made having

slag for its hydraulic base, the term "slag cement" should be dropped and the generic term *Puzzolan* be used in advertisements and specifications for such mixtures not subsequently calcined.

Puzzolan cement made from slag is characterized physically by its light lilac color; the absence of grit attending fine grinding and the extreme subdivision of its slaked-lime element; its low specific gravity (2.6 to 2.8) compared with Portland (3 to 3.5); and by the intense bluish-green color in the fresh fracture after long submersion in water, due to the presence of sulphides, which color fades after exposure to dry air.

The oxidation of sulphides in dry air is destructive of Puzzolan cement mortars and concretes so exposed. Puzzolan is usually very finely ground, and when not treated with soda sets more slowly than Portland. It stands storage well, but cements treated with soda to quicken setting become again very slow-setting from the carbonization of the soda (as well as the lime) element after long storage.

Puzzolan cement properly made contains no free or anhydrous lime, does not warp or swell, but is liable to fail from cracking and shrinking (at the surface only) in dry air.

Mortars and concretes made from Puzzolan approximate in tensile strength similar mixtures of Portland cement, but their resistance to crushing is less, the ratio of crushing to tensile strength being about 6 or 7 to 1 for Puzzolan and 9 to 11 to 1 for Portland. On account of its extreme fine grinding Puzzolan often gives nearly as great tensile strength in 3 to 1 mixtures as neat.

Puzzolan permanently assimilates but little water compared with Portland, its lime being already hydrated. It should be used in comparatively dry mixtures well rammed, but while requiring little water for chemical reactions, it requires for permanency in the air constant or continuous moisture.

PROPER USES OF PUZZOLAN CEMENT.—Puzzolan cement never becomes extremely hard like Portland, but Puzzolan mortars and concretes are tougher or less brittle than Portland.

The cement is well adapted for use in sea-water, and generally in all positions where constantly exposed to moisture, such as in foundations of buildings, sewers, and drains, and in underground works generally, and in the interior of heavy masses of masonry or concrete.

It is unfit for use when subjected to mechanical wear, attrition, or blows. It should never be used where it may be exposed for

long periods to dry air, even after it has well set. It will turn white and disintegrate, due to the oxidation of its sulphides at the surface under such exposure.

Sulphuretted hydrogen, which is often evolved upon decomposition of the sulphides in Puzzolan cement, is injurious to iron and steel.

Such metals, if used in connection with Puzzolan cement should be protected, or an allowance be made for deterioration by increase of section."

Some more recent tests of slag cements show that they contain very little sulphur and analyses show their composition to be practically the same as the best brands of Portland cements.

SPECIFICATIONS FOR PUZZOLAN CEMENT.

PREPARED BY THE U. S. ENGINEER DEPARTMENT.

(1) The cement shall be a Puzzolan of uniform quality, finely and freshly ground, dry, and free from lumps, made by grinding together without subsequent calcination granulated blast-furnace slag with slaked lime.

(2) The cement shall be put up in strong sound barrels well lined with paper, so as to be reasonably protected against moisture, or in stout cloth or canvas sacks. Each package shall be plainly labelled with the name of the brand and of the manufacturer. Any package broken or containing damaged cement may be rejected or accepted as a fractional package at the option of the United States agent in local charge.

(3) Bidders will state the brand of cement which they propose to furnish. The right is reserved to reject a tender for any brand which has not given satisfaction in use under climatic or other conditions of exposure of at least equal severity to those of the work proposed, and for any brand from cement works that do not make and test the slag used in the cement,

(4) Tenders will be received only from manufacturers or their authorized agents.

(The following paragraph will be substituted for paragraphs 3 and 4 above when cement is to be furnished and placed by the contractor.

No cement will be allowed to be used except established brands of high-grade Puzzolan cement which have been in

successful use under similar climatic conditions to those of the proposed work and which come from cement works that make the slag used in the cement.

(5) The average weight per barrel shall not be less than 330 pounds net. Four sacks shall contain 1 barrel of cement. If the weight as determined by test weighings is found to be below 330 pounds per barrel, the cement may be rejected or, at the option of the engineer officer in charge, the contractor may be required to supply, free of cost to the United States, an additional amount of cement equal to the shortage.

(6) Tests may be made of the fineness, specific gravity, soundness, time of setting, and tensile strength of the cement.

(7) FINENESS.—Ninety-seven per cent of the cement must pass through a sieve made of No. 40 wire, Stubb's gauge, having 10,000 openings per square inch.

(8) SPECIFIC GRAVITY.—The specific gravity of the cement, as determined from a sample which has been carefully dried, shall be between 2.7 and 2.8.

(9) SOUNDNESS.—To test the soundness of cement, pats of neat cement mixed for five minutes with 18 per cent of water by weight shall be made on glass, each pat about 3 inches in diameter and one-half inch thick at the centre, tapering thence to a thin edge. The pats are to be kept under wet cloths until finally set, when they are to be placed in fresh water. They should not show distortion or cracks at the end of twenty-eight days.

(10) TIME OF SETTING.—The cement shall not acquire its initial set in less than forty-five minutes and shall acquire its final set in ten hours. The pats made to test the soundness may be used in determining the time of setting. The cement is considered to have acquired its initial set when the pat will bear, without being appreciably indented, a wire one-twelfth inch in diameter loaded to one-fourth pound weight The final set has been acquired when the pat will bear, without being appreciably indented, a wire one twenty-fourth inch in diameter loaded to 1 pound weight.

(11) TENSILE STRENGTH.—Briquettes made of neat cement, after being kept in air under a wet cloth for twenty-four hours and the balance of the time in water, shall develop tensile strengths per square inch as follows:

After seven days, 350 pounds; after twenty-eight days, 500 pounds.

Briquettes made of one part cement and three parts standard sand by weight shall develop tensile strength per square inch as follows:

After seven days, 140 pounds; after twenty-eight days, 220 pounds.

(12) The highest result from each set of briquettes made at any one time is to be considered the governing test. Any cement not showing an increase of strength in the twenty-eight-day tests over the seven-day tests will be rejected.

(13) When making briquettes neat cement will be mixed with 18 per cent of water by weight, and sand and cement with 10 per cent of water by weight. After being thoroughly mixed and worked for five minutes the cement or mortar will be placed in the briquette mould in four equal layers and each layer rammed and compressed by thirty blows of a soft brass or copper rammer, three-quarters of an inch in diameter or seven-tenths of an inch square, with rounded corners, weighing 1 pound. It is to be allowed to drop on the mixture from a height of about half an inch. When the ramming has been completed the surplus cement shall be struck off and the final layer smoothed with a trowel held almost horizontal and drawn back with sufficient pressure to make its edge follow the surface of the mould.

(14) The above are to be considered the minimum requirements. Unless a cement has been recently used on work under this office, bidders will deliver a sample barrel for test before the opening of bids. If this sample shows higher tests than those given above, the average of tests made on subsequent shipments must come up to those found with the sample.

(15) A cement may be rejected in case it fails to meet any of the above requirements. An agent of the contractor may be present at the making of the tests, or, in case of the failure of any of them, they may be repeated in his presence. If the contractor so desires, the engineer officer in charge may, if he deems it to the interest of the United States, have any or all of the tests made or repeated at some recognized testing laboratory in the manner herein specified, all expenses of such tests to be paid by the contractor. All such tests shall be made on samples furnished by the engineer officer from cement actually delivered to him.

Silica Cement, or Sand Cement.—This is a patented article manufactured by grinding together silica or clean sand

with Portland cement, by which process the original cementing material is made extremely fine and its capacity to cover surfaces of concrete aggregates is much increased.

The sand is an adulteration, but on account of the extreme fineness of the product it serves to make mortar or concrete containing a given proportion of pure cement much more dense, the finer material being increased in volume.

The increase in cementing capacity due to the fine grinding of the cement constituent offsets, in great degree, the effects of the sand adulteration, so that sand cement made from equal weights of cement and sand approximates in tensile strength to the neat cement, and the material is sold as cement.

The extreme fine grinding also improves cement that contains expansives, but nevertheless sand cement should not be purchased in the market, but should be made on the work from approved materials if used for other purposes than for grouting, for which it is peculiarly adapted.

SPECIFICATIONS FOR CEMENTS.

Natural Cement.—All natural cement must have a specific gravity of not less than 2.70, must be of such fineness that 80 per cent will pass through a No. 100 standard sieve, and briquettes made of such neat natural cement, after exposure to the air for one day and immersion in water for six days, must show a tensile strength of 90 pounds to the square inch. Pats ½ inch thick must stand same test hereinafter specified for Portland cement.

Portland Cement.—All Portland cement must have a specific gravity of not less than 3.10, must be of such fineness that 90 per cent will pass through a No. 100 standard sieve, must not contain more than 2 per cent anhydrous sulphuric acid, nor 3 per cent magnesia, and briquettes made of such neat Portland cement, after exposure to the air for one day and immersion in water for six days, must show a tensile strength of 350 pounds to the square inch. One-half-inch pats exposed to the air for seven days or immersed in water for the same time after hard set shall show no blotches, discolorations, checks, or signs of disintegration.

Non-staining Cement.—Non-staining cement must be of a brand that has been in use for at least two years to test its

non-staining qualities, have a specific gravity of not less than 2.75, contain not more than 2 per cent sulphuric acid, nor more than 3 per cent magnesia, be of such fineness that 85 per cent will pass through a No. 100 standard sieve, and briquettes of the neat cement, tested as specified for Portland cement, shall have a tensile strength of 200 pounds per square inch.

All cement must be of uniform quality and when delivered must be in original packages with the brand and maker's name marked thereon, and must be kept dry.

Tests, etc., of Cement.—In ordinary work the superintendent can be guided as to the quality of the cement by the brand and name of the manufacturer; unless the cement is of a standard brand and make, and which has been thoroughly tested in the past by use, etc., the superintendent should not permit any of it to be used until it has been tested. This is best done at some laboratory equipped for the purpose.

The following rules have been adopted by the U. S. Engineer Corps for testing cement, and should be a good guide for the superintendent.

General Considerations.—The constructing engineer is confronted by no problem more difficult than to decide whether a certain cement, when placed in a work, will behave in a predetermined way. This is especially true of Portlands. Other cements are much more reliable under conditions of exposure for which they are suited.

The difficulties arise from the fact that tests for acceptance or rejection must be made on a product not in its final stage. A cement, when incorporated in masonry, undergoes for months chemical changes in the process of setting, so that the material subjected to strains in the work is not the material tested, but a derivative of it. The object of tests is to establish two probabilities: First, that the product of the given cement will develop the desired strength and hardness soon enough to enable it to bear the stresses designed for it; second, that it will never thereafter fall below that strength and hardness. Up to the present time it appears that the relation between the chemical and physical properties of raw cement and of its partially indurated derivatives, determined by tests, and the physical properties of the same cement or its derivatives, after complete hydration and induration in the work, can be stated only within rather wide limits.

The most useful tests of cements are those, first, which connect themselves definitely with some serious defect to which cements are subject, or with some merit which they should possess; second, which can be made with the least apparatus and manipulation, and which give their indications in the shortest time; and, third, which are freest from personal equation and from influences of local surroundings. These criteria, applied to the customary tests of cements, give indications as to their relative value and the best methods of making them.

Test of Grinding.—This test derives importance from the fact, apparently well established, that, other things being equal, the finer the cement the greater will be its sand-carrying capacity; that is, it will show greater strength with the same charge of sand, or equal strength with a greater charge. According to the best information the Board can obtain, the cementitious value of this material is believed to reside principally, if not wholly, in the very fine part. It follows that a grinding test should be directed to determining the proportion which it very fine rather than the residue above a certain size. The Board does not propose any change in the accepted grinding test of Portland cement, but favors for natural cement the use of the same size screen as for Portland, No. 100, with the requirement that 80 per cent shall pass through it. The screen should be frequently examined, magnified, if practicable, to see that no wires are displaced, leaving apertures larger than the normal.

Test for Specific Gravity.—This test is made with simple appliances, and its result is immediately known. It appears to connect itself quite definitely with the degree of calcination which the cement has received. The higher the burning, short of vitrification, the better the cement and the higher the specific gravity.

This test has another value, in that the adulterations of Portland cement most likely to be practised and most to be feared are made with materials which reduce the specific gravity. The test is therefore of value in determining a properly burned, non-adulterated Portland. If underburned, the specific gravity may fall below 3; it may reach 3.5 if the cement has been overburned. No other hydraulic cement is so heavy in proportion to volume, natural cement having a specific gravity of about 2.5 to 2.8 and Puzzolan (slag) of about 2.7 to 2.8. Properly burned Portland, adulterated with slag, will fall below 3.1.

Test of Activity.—This test, made by gauging the cement with water and observing the times of initial and permanent set, is partly direct and partly indirect. It is direct in so far as its limits relate to the time necessary to get the cement in place after mixing, which must not be greater than the time of initial set, and to the time within which the cement product must take its load, which must not be less than the time of permanent set. It is indirect in so far as its limits relate to the probable final strength, elasticity, and hardness of the cement mixtures. In the latter respect it appears to be reasonably well established that cements exhibiting great activity give, after long periods, results inferior to those with action less rapid.

The test for activity is easily made with simple appliances, and its results are known in a few hours at most. Variable results in the test are caused by different local conditions of moisture and temperature and by the different judgments of observers as to whether the needles penetrate or not. Generally speaking, both periods of set are lengthened by increase of moisture and shortened by increase of temperature. Some manufacturers claim that their cements show their best results when gauged with particular percentages of water. It is not considered good policy to encourage these peculiarities at the expense of the uniformity of tests which is so greatly desired. It is better to adopt a definite proportion of water for gauging and require all cements of the same class to stand or fall on their showing when so gauged. Such a percentage, adopted and known, will probably be used by manufacturers in testing goods sold to the Engineer Department, and a greater harmony between mill and field tests of the same cement will result.

In gauging Portland cement the samples should be thoroughly dried before adding water. This precaution is not deemed necessary with natural cement. Sufficient uniformity of temperature will result if the testing-room be comfortably warmed in winter and the specimens be kept out of the sun in a cool room in summer and under a damp cloth until set.

Test for Constancy of Volume.—This test results from observations made on the pats or cakes used in the setting test. It derives its value from its connection with the quantity of expansives in the cement.

The test is easy to make, and its results are relatively free

from personal error, though there is room for a difference of judgment as to the appearance of the cakes. As they may be preserved and the decision reviewed at any time on the original data, such differences are immaterial.

TESTS OF STRENGTH.—These may be subdivided into compressive and tensile tests, the latter including the transverse test made by breaking a beam of the cement. The compressive test need not be further considered, as it is less easily made than the tensile test and gives no surer indications. The ratio of compressive to tensile strength of the same class of cements is quite uniform.

Of the tensile tests the direct pull is preferable to the flexure test.

The tensile test is theoretically a perfect index of the quality of the cement at the periods of test, and a comparison at different periods gives the best obtainable indication of what its subsequent conduct will be. In the opinion of the Board the two periods most generally adopted, seven and twenty-eight days after mixing, are, on the whole, the best. The one-day test, though of some value in a discriminating sense, should not be placed in the same category as the other periods named.

The apparatus for tensile tests is somewhat elaborate and delicate, but is of standard manufacture and readily obtainable at relatively small cost.

In respect of uncertainties due to the personal equation of the tester and to the influence of local conditions this test presents greater difficulties than any of the others considered. The most scrupulous care must be observed in the manipulations, and the tester should possess natural aptitude for such work. The object is to determine the greatest stress per square inch which the cement can be made to stand under given conditions without rupture. If the conditions have been carefully observed and several discrepant results are obtained, the highest may be right, but the others are certainly wrong. No averaging should be done.

The remarks made above under the activity test as to the relation between early hydraulic intensity and the final excellence of a cement product are equally applicable to the indications from tensile tests. A cement which tests moderately high at seven days and shows a substantial increase to twenty-eight days is more likely to reach the maximum strength slowly

and retain it indefinitely with a low modulus of elasticity than a cement which tests abnormally high at seven days with little or no increase at twenty-eight days.

Accelerated Tests.—The rules recommended by the committee of the American Society of Civil Engineers in 1885 have been substantially accepted here and abroad as to tests of setting qualities and soundness; more rapid tests for soundness are, however, proposed and practised, though no accelerated test has been generally accepted.

Accelerated tests proposed for the speedy detection of the presence of expansives in cement usually consist in the application, after gauging, of dry heat or of immersion in warm or boiling water or steam. The immersion tests are most in vogue. They vary from immersing freshly gauged pats on glass plates in water at 115° F. for twenty-four hours, or at higher temperatures for various periods, to steaming or boiling cakes or cylinders of the material to be tested at 212° F. for varying times.

In France and Germany the swelling or expansion of boiled cylinders is measured directly by calibration. Usually change of volume not accompanied by visible evidences of it—i.e., distortion or disruption—is not observed in American tests prescribed in specifications for the reception of cements. Of all these tests the boiling test is the simplest, requires only apparatus everywhere available, and is recommended by the Board. It has been the experience that this test detects material that is unsound by reason of the presence of active expansives; but in some cases it rejects material that would give satisfactory results in actual work and will reject material that would stand this test after air slaking.

The great value of the test lies in its short-time indications and in at once directing attention to weak points in the cement to be further observed or guarded against. Of two or more cements offered for use or on hand, the cements that stand the boiling tests are to be taken preferably; it should be constantly applied on the work among other simple tests to be noted, for although the boiling test sometimes rejects suitable material, it is believed that it will always reject a material unsound by reason of the existence of active expansives. Sulphate of lime, while enabling cements to pass the boiling tests, introduces an element of danger.

This test is proposed as suggestive or discriminative only.

Except for works of unusual importance it is not recommended that a cement passing the other tests proposed shall be rejected on the boiling test.

Tests to be Made.—For selecting Portland and Puzzolan cements from among the brands offered, the Board recommends that the following tests be made:

1. For fineness of grinding.
2. For specific gravity.
3. For soundness or constancy of volume in setting.
4. For time of setting.
5. For tensile strength.

For natural cement we recommend the omission of the specific-gravity and soundness tests.

On the works the Board recommends simple tests when the more elaborate tests cannot well be made.

In determining the minimum requirements for cements given in the subjoined specifications we recognize that many cements that attain only fair strength neat and with sand in a short time and show marked gains of strength on further time will fulfil the requirements of the service, and that unusually high tensile strength attained in a few days after gauging is often coupled with a small or negative increase in strength in further short intervals. Unusually high tests in a short time after gauging should be regarded with suspicion, although some well-known brands of American cements show great strength in short-time tests and, so far as observed, are reliable in air and fresh water. Cements offered under such known brands should show their characteristic strength and other qualities or be suspected as spurious or adulterated, if not rejected, even though the minimum requirements of the specifications are met. The practice of offering a bonus or free gift of money in addition to the contract price for cement testing above a fixed high point should be prohibited as unnecessary, for cements so obtained are likely to be unsound in a manner not easily detected in the time usually available in testing.

It is believed that most of the very high-testing Portland cements have lime in excess, the effect of which is temporarily masked by the use of sulphate of lime. Overlined cements so treated are unfit for use in sea-water. For such uses a chemical analysis should be required, and the quantity of sulphuric acid, as well as magnesia, be limited to a low per-

centage.[1] It is not yet known that sulphate of lime in quantity less than 2 per cent is injurious to cements to be used in fresh water or in air. It masks expansives that might ultimately cause the destruction of the work, but it is not known whether this effect is permanent. Its addition is now deemed necessary to control time of setting. It makes a quick-setting cement slow setting, at the same time increasing tensile strength acquired in a short time.

MANIPULATION OF CEMENTS FOR TESTS.—*I. Fineness.*—Place 100 parts (denominations determined by subdivisions of the weighing-machine used) by weight on a sieve with 100 holes to the linear inch, woven from brass wire No. 40, Stubb's wire gauge; sift by hand or mechanical shaker until cement ceases to pass through.

The weight of the material passing the sieve plus the weight of the dust lost in air, expressed in hundredths of the original weight, will express the percentage of fineness. In order to determine this percentage the residue on the sieve should be weighed.

It is only the impalpable dust that possesses cementitious value. Fineness of grinding is therefore an essential quality in cements to be mixed with sand. The residue on a sieve of 100 meshes to the inch is of no cementitious value, and even the grit retained on a sieve of 40,000 openings to the square inch is of small value. The degree of fineness prescribed in these specifications (92 per cent) for Portland through a sieve of 10,000 meshes to the square inch is quite commonly attained in high-grade American cements, but rarely in imported brands. On the Pacific Coast, where foreign cements mainly are in the market, this requirement may be lowered for the present to 87 per cent on No. 100 sieve.

II. Specific Gravity.—The standard temperature for specific-gravity determinations is 62° F., but for cement testing temperatures may vary between 60° and 80° F. without affecting results more than the probable error in the observation.

Use any approved form of volumenometer or specific-gravity bottle, graduated to cubic centimeters with decimal subdivisions. Fill instrument to zero of the scale with benzine, turpentine, or some other liquid having no action upon cements.

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[1] Not more than 3 per cent, by weight, of magnesia, 1 per cent of sulphuric anhydride, or 2 per cent of sulphate of lime should be allowed in any case. In sea-water not exceeding one-half these quantities.

Take 100 grams of sifted cement that has been previously dried by exposure on a metal plate for twenty minutes to a dry heat of 212° F., and allow it to pass slowly into the fluid of the volumenometer, taking care that the powder does not stick to the sides of the graduated tube above the fluid and that the funnel through which it is introduced does not touch the fluid.

Read carefully the volume of the displaced fluid to the nearest fraction of a cubic centimeter. Then the approximate specific gravity will be represented by 100 divided by the displacement in cubic centimeters.

The operation requires care.

III. Setting Qualities and Soundness.—The quantity of water and the temperature of water and air affect the time of setting. The specifications contemplate a temperature varying not more than 10° from 62° F. and quantities of water given herein:

For Portland cements use about 20 per cent of water.

For Puzzolan cements use about 18 per cent of water.

For natural cements use about 30 per cent of water.

These quantities are for the cements as taken from the packages.

Mix thoroughly for five minutes, vigorously rubbing the mixture under pressure; time to be estimated from moment of adding water and to be considered of importance.

Make on glass plates two cakes from the mixture about 3 inches in diameter, $\frac{1}{2}$ inch thick at middle, and drawn to thin edges, and cover them with a damp cloth or place them in a tight box not exposed to currents of dry air. At the end of the time specified for initial set apply the needle $\frac{1}{12}$ inch diameter weighted to $\frac{1}{4}$ pound to one of the cakes. If an indentation is made the cement passes the requirement for initial setting, if no indentation is made by the needle it is too quick-setting. At the end of the time specified for "final set" apply the needle $\frac{1}{24}$ inch diameter loaded to 1 pound. The cement cake should not be indented.

Expose the two cakes to air under damp cloth for twenty-four hours. Place one of the cakes, still attached to its plate, in water for twenty-eight days; the other cake immerse in water at about 70° temperature supported in a rack above the bottom of the receptacle; raise the water gradually to the boiling-point and maintain this temperature for six hours and then let the water with cake immersed cool. Examine the

cakes at the proper time for evidences of expansion and distortion. Should the boiled cake become detached from the plate by twisting and warping or show expansion cracks the cement may be rejected, or it may await the result of twenty-eight days in water. If the fresh-water cake shows no evidences of swelling, the cement may be used in ordinary work in air or fresh water for lean mixtures. If distortion or expansion cracks are shown on the fresh-water cake, the cement should be rejected.

Of two or more cements offered, all of which will stand the fresh-water-cake test for soundness, the cements that will stand the boiling tests also are to be preferred.

IV. Tensile Strength.—Neat Tests: Use thoroughly dried unsifted cements.[1] Place the amount to be mixed on a smooth, non-absorbent slab; make a crater in the middle sufficient to hold the water; add nearly all the water at once, the remainder as needed; mix thoroughly by turning with the trowel, and vigorously rub or work the cement for five minutes.

Place the mould on a glass or slate slab. Fill the mould with consecutive layers of cement, each when rammed to be ¼ inch thick. Tap each layer 30 taps with a soft brass or copper rammer weighing 1 pound and having a face ¾ inch diameter or 7/10 inch square with rounded corners. The tapping or ramming is to be done as follows: While holding the forearm and wrist at a constant level, raise the rammer with the thumb and forefinger about ½ inch and then let it fall freely, repeating the operation until the layer is uniformly compacted by 30 taps.

This method is intended to compact the material in a manner similar to actual practice in construction, when a metal rammer is used weighing 30 pounds, with circular head 5 inches in diameter falling about 8 inches upon layers of mortar or concrete 3 inches thick. The method permits comparable results to be obtained by different observers.

After filling the mould and ramming the last layer, strike smooth with the trowel, tap the mould lightly in a direction parallel to the base plate to prevent adhesion to the plate, and

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[1] The hot clinker is often suddenly chilled by steam or water in order to reduce the work of grinding by first cracking it. This water, as well as that absorbed from the air, should always be expelled or its percentage ascertained and deducted from the amounts prescribed for briquettes. Sand, also, should be similarly treated.

cover for twenty-four hours with a damp cloth. Then remove the briquette from the mould and immerse it in fresh water, which should be renewed twice a week for the specified time if running water is not available for a slow current. If moulds are not available for twenty-four hours, remove from the moulds after final set, replacing the damp cloth over the briquettes. In removing briquettes before hard set great care should be exercised. Hold the mould in the left hand and, after loosening the latch, tap gently the sides of the mould until they fall apart. Place the briquettes face down in the water trough.

For neat tests of Portland cement use 20 per cent of water by weight.

For neat tests of Puzzolan cement use 18 per cent of water by weight.

For neat tests of natural cement use 30 per cent of water by weight.

Nearly all this water is retained by Portland cement, whereas only about one-third of the gauging water is retained by Puzzolan or natural cements; from this it follows that an apparent condition of plasticity or fluidity that ultimately little injures Portland paste, very seriously injures Puzzolan or natural mortars and concretes by leaving a porous texture on the evaporation of the surplus water.

Sand Tests.—The proportions 1 cement to 3 sand are to be used in tests of Puzzolan and Portland, and 1 cement to 1 sand in tests of natural or Rosendale cements. Crushed quartz sand, sifted to pass a standard sieve with 20 meshes per linear inch and to be retained on a standard sieve with 30 meshes to the inch, is to be used.

After weighing carefully, mix dry the cement and sand until the mixture is uniform, add the water as in neat mixtures, and mix for five minutes by triturating or rubbing together the constituents of the mortar. This may be done under pressure with a trowel or by rubbing between the fingers, using rubber gloves. The rubbing together seems necessary to coat thoroughly the facets of the sand with the cement paste.

It is found that prolonged rubbing, when not carried beyond the time of the initial set, results in higher tests. Five minutes is the time of mixing quite generally adopted in European specifications. The briquettes are to be made as prescribed for neat mixtures.

Portland cements well dried require water from 10 to 12½ per cent by weight of constituent sand and cement for maximum ultimate strength in tested briquettes.

Puzzolan, about 9 to 10 per cent.

Natural, about 15 to 17 per cent.

Mixtures that at first appear too dry for testing purposes often become more plastic under the prolonged working required herein.

In general, about four briquettes constitute the maximum number that may be made well within the time required for initial setting of moderately slow-setting cements.

Three such batches of sand mixtures should be made, and one briquette of each batch may be broken at seven and twenty-eight days, giving three tests at each period. At least one batch of neat cement briquettes should be made.

If the first briquette broken at each date fulfils the minimum requirement of these specifications it is not necessary to break others which may be reserved for long-time tests.

If the first briquette does not pass the test for tensile strength, then briquettes may be broken until six briquettes, two from each batch, have been broken at seven days, and the remaining six reserved for twenty-eight-day tests. The highest result from any sample is to be taken as the strength of the sample when the break is at the least section of briquette.

If, on the twenty-eight-day tests, the cement not only more than fulfils the minimum requirements of these specifications, but also shows unusual gain in strength, it may still be accepted if the other tests are satisfactory, notwithstanding a low seven-day test, if early strength is not a matter of importance. Such cements are likely to be permanent.

For a batch of four briquettes, the following quantities are suggested as in accord with these specifications. Water is measured by fluid-ounce volumes, not by weight, temperature varying not more than 10° from 62° F.

Portland Cement.—Neat: 20 ounces of cement, 4 ounces of water. Mix wet five minutes.

Sand: 15 ounces sand, 5 ounces cement, 2½ ounces water. Mix thoroughly dry; then mix wet five minutes.

Puzzolan Cement.—Neat: 20 ounces cement, 3¾ ounces water. Mix wet five minutes.

Sand: 15 ounces sand, 5 ounces cement, 2 ounces water. Mix thoroughly dry; then mix wet five minutes.

Natural Cement.—Neat: 20 ounces cement, 6 ounces water. Mix wet five minutes.

Sand: 10 ounces cement, 10 ounces sand, 3½ ounces water. Mix dry; then wet for five minutes.

For measuring tensile strength, a machine that applies the stress automatically at a uniform rate is preferable to one controlled entirely by hand.

These specifications for tensile strength contemplate the application of stress at the rate of 400 pounds per minute to briquettes made as prescribed herein. A rate so rapid as to approximate a blow or so slow as to approximate a continued stress will give very different results.

The tests for tensile strength are to be made immediately after taking from the water or while the briquettes are still wet. The temperature of the water during immersion should be maintained as nearly constant as practicable; not less than 50° nor more than 70° F.

The tests are to be made upon briquettes 1 inch square at place of rupture. The specifications contemplate the use of the form of briquette recommended by the committee of the American Society of Civil Engineers, held when tested by close-fitting metal clips, without rubber or other yielding contacts. The breaks considered in the tests are to be those occurring at the smallest section, 1 inch square.

Simple Tests.—Tests of cement received upon a work in progress must often be of much simpler character than prescribed herein.

Tests on the work are mainly to ascertain whether the article supplied is genuine cement, of a brand previously tested and accepted, and whether it is a reasonably sound and active cement that will set hard in the desired time, and give a good, hard mortar. Simple tests may give this information, and such should be multiplied whether or not more elaborate tests be made. Pats and balls of cement and mortar from the storehouse and mixing platform or machine should be frequently made. The setting or hardening qualities, as determined roughly by estimating time and by pressure of the thumb-nail, should be observed; the hardness of the set and strength, by cracking the hardened pats or cakes between the fingers, and by dropping the balls from the height of the arm upon a pavement or stone and observing the result of the impact.

By placing the pats in water as soon as hardened sufficiently

and raising the temperature to the boiling-point for a few hours and observing the character and color of the fracture after sufficient immersion, information as to the character of the material, whether hydraulic, a Portland, or Puzzolan, whether too fresh or possibly "blowy," may be speedily and quite well ascertained without measuring instruments.

Many engineers and users of cements regard such simple tests, taken in connection with the weight and fineness of the cement and the apparent texture and hardness of the mortars and concretes in the work, sufficient field tests of a material of known repute. The more elaborate tests, described above, should be made in well-equipped laboratories by skilled cement testers.

Classification of Tests.—The tests to be made are two classes.

(1) Purchase tests on samples furnished by bidders to ascertain whether the bidder may be held on the sample to the delivery of suitable material, should his offer be accepted.

(2) Acceptance tests on samples taken at random from deliveries, to ascertain whether the material supplied accords with the purchase sample, or is suitable for the purpose of the work, as stated in the specifications for cement supplies.

(1) *Purchase tests.*—Under these specifications bids for Portland cements will be restricted to brands that have been approved after at least three years' exposure in successful use under similar conditions to those of the proposed work. This specification limits proposals to manufacturers of cement of established repute, and in so far lessens the dependence to be placed upon tests of single samples of cement in determining the probable quality of the cements offered, that sample packages may not be required with the proposals when the brand is known to the purchaser. When the cement is not known to the purchasing officer by previous use, a barrel of it should be required as representing the quality of cement to be supplied. A full set of tests should be made from this sample, and subsequent deliveries be required to show quality at least equal to the sample.

In this connection it is advisable in districts where well-equipped laboratories have been established, that sample packages of the cements in use in that territory, as sold in the open market, be obtained and tested as occasion offers to ascertain the characteristic qualities of the brands as commer-

cial articles, the information to be used in subsequent purchases of cements.

When purchase samples are waived, acceptance tests should be based upon the known qualities of the brand, as shown by previous tests.

The sample barrel should not be broken further than to take therefrom the necessary samples for testing. Afterwards it should be put away in a dry place and kept for further testing, should the results obtained be disputed.

(2) *Acceptance tests.*—The tests to be made on cements delivered under contract depend not only on the extent, character, and importance of the work itself, but also on the time available between the delivery and the actual use of the material.

(*a*) On very important and extensive works, equipped with a testing laboratory and adequate storehouses, where cement may be kept at least thirty days before being required for use, full and elaborate tests should be made, keeping in view the fact that careful tests of few samples are more valuable than hurried tests of many samples.

(*b*) On active works of ordinary character, when time will not permit full tests, and on small works where the expenses of a laboratory are not justified, the tests must necessarily be limited to such reasonable precautions against the acceptance and use of unfit material as may be taken in the usually short interval between the receipt and use of the material.

Such conditions were in view in formulating the specification that proposals will be received from manufacturers of such cements only as have been proved by at least three years' use under similar conditions of exposure. Of the tests named in the specifications, those for fineness, activity or hydraulicity, specific gravity, weight of packages, and accelerated tests for indications as to soundness, may be made within two days after the receipt of the material and with a very small outlay for instruments.

Cement of established repute, shown by specific gravity and fineness to be properly burnt and ground, or normal for the brand, that will set hard in reasonable time, the cakes snapping with a clean fracture when broken between the fingers, and standing the tests above named, may be accepted and used with reasonable certainty of success. Nevertheless, packages taken at random from the deliveries should occasionally be set aside and samples taken therefrom sent to a testing

laboratory for the more elaborate tests for tensile strength (and for soundness should the boiling tests not be conclusive). The final acceptance and payment for such cement as may not have been actually placed in the work should, by agreement, be made to depend upon such tests.

In all cases where cement has been long stored it should be carefully tested before use to ascertain whether it has deteriorated in strength.

Should the simple tests give unsatisfactory or suspicious results, then a full series of tests should be carefully made.

When Portland cement is in question the specific-gravity and fineness tests should be made to guard against adulteration, and in all cases test weighings should be made to guard against short weights.

In cases where the amount of cement or the importance of the work will not justify the purchase of the simple apparatus required for the specific gravity, fineness, and boiling tests, the cement can be accepted on the informal tests mentioned herein, which require no apparatus whatever, but in such cases cements well known to the purchaser by previous use should be selected and purchased directly from the manufacturer or his selling agent in order that responsibility for the cement may be fixed.

Certified tests by professional inspectors made as prescribed herein on samples taken from the cement to be shipped to the work, in a manner analogous to that cutsomary among engineers in the purchase of structural steel and iron, may be required in such cases.

SAMPLING.—The entire package from parts of which tests are to be made is to be regarded as the sample tested. It should be marked with a distinctive mark that must also be applied to any part tested. The package should be set aside and protected against deterioration until all results from tests made from it are reached and accepted by both parties to the contract for supplies.

Cement drawn from several sample packages should not be mixed or mingled, but the individuality of each sample package should be preserved.

In testing it should be borne in mind that a few tests from any sample, carefully made, are more valuable than many made with less care.

The amount of material to be taken for formal tests is indicated herein where weights of the constituents of four briquettes are given, to which should be added the amount necessary for the tests for specific gravity, activity, and soundness.

In extended tests the material should be taken from the sample package from the heads and centre of barrel, and from the ends and centre of bag, by such an instrument as is used by inspectors of flour. All material taken from the same sample package may be thoroughly mixed or mingled and the tests be made therefrom as showing the true character of the contents of the sample package.

In making formal tests at the work for acceptance of cement sample packages should be taken at random from among sound packages. The number taken must depend upon the importance and character of the work, the available time, and the capacity of the permanent laboratory force. For tensile strength the tests with sand are considered the more important and should always be made. Tests neat should be made if time permits.

It is not necessary in any case on a large work to test more than 10 per cent of the deliveries, even of doubtful cement, and a much less number of samples may be taken should no cause for distrust be revealed by the tests made. In very important work of small extent each package may be tested. A cement should be rejected if the samples show dangerous variation in quality or lack of care in manufacture and resulting lack of uniformity in the produce without regard to the proportion of failures among samples tested.

In all cases in the use of cements the informal or simple tests of the character named herein should be constantly carried on. These constitute most valuable tests. Whenever any faulty material is indicated by such tests, elaborate tests should be at once instituted and should the fault be confirmed, the cement delivered and not used should be rejected and the use of the brand be discontinued.

Tests for Weight.—From time to time packages should be weighed in gross and afterwards the weight of neat cement and tare of the packages determined. If short weight of neat cement is indicated, a sufficient number of packages should be weighed and the average net weight per package ascertained with sufficient certainty to afford a satisfactory basis of settlement.

The superintendent may make some simple tests to determine the quality of the cement as follows:

SOUNDNESS.—To test the soundness of the cement, take a lamp-chimney with a large swell to it and stand it on end; fill it with dry cement and then pour water on the cement; if the glass cracks the cement is unfit for use in any damp place.

The cement can be tested as to the time the initial set takes place; as a rule the longer it takes the cement to set the stronger it will be.

A simple test can be made by mixing some cement with just enough water to make it plastic, and roll it into a ball about the size of a walnut; after it sets in the air for about two hours, place it under water for three or four days If it gradually becomes harder with no cracks it is an indication of good cement.

EXPANSION.—A cement that will expand should not be used. To test this make a cake of cement and let it remain in the air until it sets, then put it under water for a few days; if any cracks appear around the edge of the cake it indicates expansion and should be rejected. This sometimes happens with newly made cement, and age will overcome it. The test for soundess will also generally show if the cement will expand.

NON-STAINING CEMENT.—In setting or pointing marble or limestones or other porous stones a reliable brand of a non-staining cement should be used, as Portland or Rosendale cement will stain the stone enough to disfigure it. This is a patent cement called La Farge, which is usually made from a limestone having hydraulic qualities. Some of the foreign Puzzolan cements also possess this non-staining feature.

Notes Regarding Cement.

NUMBER AND MESH OF SIEVES FOR TESTING CEMENT.

No. 50............	2500 meshes to the square inch
No. 74............	5476 meshes to the square inch
No. 100............	10,000 meshes to the square inch
No. 200............	40,000 meshes to the square inch

The porosity of mortar and cement, according to recent tests made by Prof. Lang, shows that when wet Portland-cement

concrete is impermeable to air. By measuring the amount of air which passes a layer of given thickness, under a certain pressure, in a unit of time, the following values for the degree of permeability were obtained:

	Dry.	Wet.
Portland cement, neat..................	0.05	0.00
Portland-cement concrete...............	0.40	0.00

The specific gravity of Portland cement is between 3.10 and 3.25.

The specific gravity of cement is the figure which denotes the density of a sample or the number of times a given volume of it is weightier than the same volume of water.

For cement pipe use the following proportions: one part cement to three parts of sand and gravel. After the pipe is removed from the mould it should be coated with a wash of neat cement and water, of the consistency of paint, applied with a brush, to prevent seepage of water when in service.

Neat cement reaches a greater strength at short periods than sand mixtures. Concrete, however, gains in strength gradually, and ultimately surpasses neat cement in strength.

The compressive strength of cement is usually from eight to twelve times the tensile strength.

Quick-setting cement requires more water than slow-setting cement.

Temperature of water and atmospheric conditions naturally affect setting time.

Saline water retards setting.

A sand mixture of a cement which does not stand the neat pat test perfectly may show no imperfections whatever. Sand tends to diminish the ill effects of some inferior qualities.

Finely ground cement has greater capacity for sand, ages more rapidly, sets quicker, gets ultimate strength quicker, requires more water, is lighter in color, shows lower tensile strength in neat briquettes, shows greater tensile strength in sand briquettes, than the same cement not so finely ground. The finer the grinding, the more active the cement.

Aged cement as a rule sets slower. shows lower tensile strength in early breaks (one, three, and seven days especially), shows greater tensile strength in later breaks, is more liable to withstand pat tests, has smaller capacity for sand, than the same cement when tested fresh.

What a Barrel of Portland Cement Will Do.

A barrel of Portland cement weighs about 380 pounds net.

A barrel of Portland cement weighs about 400 pounds gross.

A barrel of Portland cement contains about 3.40 cu. ft. packed.

A barrel of Portland cement contains about 4.25 cu. ft. loose.

A barrel of Portland cement contains about 2.73 bushels packed.

A barrel of Portland cement contains about 3.61 bushels loose.

A barrel of Portland cement will make about 3.15 cu. ft. of neat mortar.

A barrel of Portland cement will make about 5.4 cu. ft. of mortar mixed 1 to 1.

A barrel of Portland cement will make about 8.5 cu. ft. of mortar mixed 1 to 2

A barrel of Portland cement will make about 10.7 cu. ft. of mortar mixed 1 to 3.

A barrel of Portland cement will make about 13.5 cu. ft. of mortar mixed 1 to 4.

A barrel of Portland cement will make about 23 cu. ft. of concrete mixed 1, 3, 5.

A barrel of Portland cement will make about 26 cu. ft. of concrete mixed 1, 3, 6.

A barrel of Portland cement will make about 29 cu. ft. of concrete mixed 1, 3, 7.

A barrel of Portland cement will make about 30 cu. ft. of concrete mixed 1, 3, 8.

A barrel of Portland cement (neat) will cover about 40 sq. ft. 1 in. thick.

A barrel of Portland cement to 1 sand will cover about 65 sq. ft. 1 in. thick.

A barrel of Portland cement to 2 sand will cover about 92 sq. ft. 1 in. thick.

A barrel of Portland cement to 3 sand will cover about 128 sq. ft. 1 in. thick.

A barrel of Portland cement to 2 sand will lay about 750 brick with $\frac{3}{8}$-in. joint.

A barrel of Portland cement to 2 sand will lay about 1050 brick with $\frac{1}{4}$-in. joint.

A barrel of Portland cement to 3 sand will lay about 900 brick with $\frac{3}{8}$-in. joint.

A barrel of Portland cement to 3 sand will lay about 1350 brick with ¼-in. joint.

A barrel of Portland cement to 3 sand will lay about 2 perches of rubble stonework.

ANALYSIS OF VARIOUS BRANDS OF CEMENT.

Brand of Cement.	Lime.	Silica	Clay and Iron Oxi'e	Magnesia.	Sulphu'c Acid.	Analysis Made by
Alpha.	63.93	20.68	10.60	2.86	.....	Manufacturer.
Atlas.	62.22	21.48	10.44	2.95	1.03	Department of Public W'ks, Brooklyn, N. Y.
Alpena.	63.35	20.52	10.50	1.93	1.24	Manufacturer's guarantee.
Buckeye.	63.50	22.25	9.75	1.75	.75	Manufacturer.
Colton.	63.05	23.00	11.50	.18	1.63	Adolph New, chemist, Colton, Cal.
Catskill.	63.21	23.44	10.34	1.15	1.25	Manufacturer.
Diamond.	63.40	20.60	12.18	1.44	.79	Superintendent of Construction, U. S. P. O., Clevel'd.
Golden Gate.	60.00	23.10	12.12	1.15	1.84	Adolph New, chemist, Colton, Cal.
Hudson.	62.98	21.60	12.07	1.27	1.33	Manufacturer.
Iroquois.	62.20	23.70	10.39	1.21	1.70	Manufacturer's guarantee.
Ideal.	64.20	23.30	8.40	.72	1.90	Adolph New, chemist, Colton, Cal.
Iron clad.	63.50	21.50	10.50	1.80	1.50	Manufacturer.
Lehigh.	62.96	22.42	9.18	2.76	1.05	Booth, Garret & Blair, Philadelphia, Pa.
Medusa.	64.78	23.30	9.44	.97	1.21	Manufacturer.
Marquette.	64.26	21.80	10.81	1.76	.96	Manufacturer's guarantee.
Napa Junction	61.00	22.50	11.50	1.08	2.00	Adolph New, chemist, Colton, Cal.
Old Dominion.	63.47	20.65	9.69	2.76	1.34	Booth, Garret & Blair, Philadelphia, Pa.
Peninsula.	64.10	22.00	10.50	.60	1.60	Manufacturer.
Saylors.	64.51	19.67	12.34	1.16	....	Manufacturer.
T. A. Edison.	62.71	20.14	10.84	2.34	1.64	Lathbury & Spackman, Philadelphia, Pa.
Universal.	61.92	23.62	11.92	1.78	1.32	Robt. Hunt & Co., Chicago.
Average.	63.10	21.98	10.65	1.61	1.37	

AVERAGE TENSILE STRENGTH IN POUNDS PER SQUARE INCH OF VARIOUS BRANDS OF PORTLAND CEMENT.

Brand of Cement.	Twenty-four Hours.		Seven Days.		Twenty-eight Days.		Six Months.		Initial Set in Minutes.	Final Set in Minutes.	Per Cent through No. 100 Sieve.	Test Made by
	Neat.	1 to 3.	Neat.	1 to 3.	Neat.	1 to 3.	Neat.	1 to 3.				
Alpha	....	....	513	160	699	206	....	....	....	....	....	U. S. Engineer Corps.
Atlas	....	....	585	252	760	475	818	497	26	288	98	City Engineer, Youngstown, Ohio.
Alsen (German)	439	....	653	214	703	282	....	....	....	....	80.5	U. S. Engineer, San Francisco.
Alpena	510	....	704	275	871	379	....	....	155	335	95.3	Department of Public Works, St. Paul, Minn.
Buckeye	....	....	330	193	518	291	....	....	....	....	....	Champion Iron Works, Kenton Ohio.
Catskill	346	....	654	....	736	....	....	....	....	....	86.4	Metropolitan Sewerage Works, Boston.
Castle (Belgian)	235	65	336	121	387	176	....	....	59	290	86	Department of Public Works, Philadelphia.
Colton	312	110	730	250	900	375	....	....	....	....	....	Adolph New, chemist, Colton, Cal.
California	137	....	618	119	719	342	....	....	....	....	86.9	U. S. Engineer, San Francisco, Cal.
Cannon	....	....	....	212	....	260	....	....	....	....	94	U. S. Engineer, San Francisco, Cal.
Comet	305	....	573	158	667	230	....	....	....	....	81.7	U. S. Engineer, San Francisco, Cal.
Condor	165	....	610	162	695	261	....	....	....	....	85.4	U. S. Engineer, San Francisco, Cal.
Chicago AA	....	....	674	264	775	463	889	606	120	345	94	H. L. Bailey Laboratory, Chicago.
Dexter	302	....	771	296	841	361	....	....	270	420	99.3	Lathbury & Spackman, New York.
Dragon	316	107	572	273	744	359	....	....	....	....	96	Illinois Central R. R. Co.
Dykerhoff (German)	249	....	481	252	....	....	....	....	300	....	92	U. S. Engineer Department, Washington.
Diamond	....	....	682	199	....	....	....	....	50	....	95	Superintendent of Construction, U. S. P. O., Cleveland.
Elk	300	....	650	200	800	275	900	450	120	300	95	Manufacturer.
English	330	....	575	....	710	....	....	....	....	....	....	City Surveyor, Charleston, S. C
Egypt	....	....	....	159	....	205	....	341	....	....	....	U. S. Engineer Department, Washington.

Giant	424	87	669	227	719	309	786	329	70	359	90.3	Board of Public Works, Philadelphia.
Germania (German)	202		594	198	745	246			180		91	U. S. Engineer Department, Washington.
Golden Gate	260		626	283	741	460					96.1	U. S. Engineer, San Francisco.
Gillingham	237		489	194	523	241						City Engineer, Los Angeles, Cal.
Green Island (Oriental)	177		452	119	564	197					84.2	U. S. Engineer, San Francisco.
Hilton's (English)	243		625	143	713	209					89.9	U. S. Engineer, San Francisco.
Helderberg	250		700	302								Manufacturer.
Heyen (German)	396	112	543	234	614	288			108	416	92.3	Board of Public Works, Philadelphia.
Hemmoor (German)	221	84	466	191	502	263			2	21	95.1	Board of Public Works, Philadelphia.
Hercules	209	47	314	90	425	135	687	265	3	21	77.9	Board of Public Works, Philadelphia.
Henry	164			159		188		319				Engineering Department, District of Columb.
Hanover				205		244		315				Engineering Department, District of Columb.
Hudson			657	223	736	354			198	328	92.4	U. S. Engineer, Tuscaloosa, Ala.
Iron Clad	176		792	302	819	370	861	496				Aqueduct Commission, New York.
Iola	178		834		904				150	300	93	Denver Union Water Co.
Iroquois	368		688	272	776	336	986	544	180	345	95	Manufacturer.
Ideal	346		710	237	847	276	843	497	146	374	97.03	City Engineer, Los Angeles.
Iron Crown			251	68	478	100					79.3	U. S. Engineer, San Francisco.
Josson	235		606	202	702	264					89.9	U. S. Engineer, San Francisco.
Lehigh	302		598	220	685	300			120	300	95	U. S. Engineer, Buffalo, N. Y.
Lagerdorfer			436	150	534	223	546	384	165		90.3	Colorado Iron Works, Pueblo, Col.
Medusa			731	196	810	300		363	183	378	93.70	U. S Engineer Corps.
Mannheimer (German)	211	74	483	177	585	237			90	295	93	Board of Public Works, Philadelphia.
Marquette	310	47	799	238	845	367					94.5	Illinois Central R. R. Co.
Nazareth	275	90	654	225	765	238			120	210	97.3	Board of Public Works, Philadelphia.
Napa Junction	225	95	630	208	670	345						Adolph New, chemist, Colton, Cal.
Owl	154	30	611	209	791	304	937	387			98	Illinois Central R. R. Co.
Old Dominion	467		878	294							93.4	U. S. Engineer Commission.
Omega			611	202	684	270					98.75	Robert Hunt & Co., Chicago.
Peninsula	196		354		566						95.05	Watertown Arsenal.
Phœnix			702	194	679	277						City Engineer, Minneapolis.

AVERAGE TENSILE STRENGTH IN POUNDS PER SQUARE INCH OF VARIOUS BRANDS OF PORTLAND CEMENT—(*Continued*).

Brand of Cement.	Twenty-four Hours.		Seven Days.		Twenty-eight Days.		Six Months.		Initial Set in Minutes.	Final Set in Minutes.	Per Cent through No. 100 Sieve.	Test Made by
	Neat.	1 to 3.	Neat.	1 to 3.	Neat.	1 to 3.	Neat.	1 to 3.				
Porta	....	....	580	209	628	243	....	543	....	....	.....	U. S. Engineer, San Francisco.
Peerless	....	....	451	182	630	253	....	....	105	250	.....	City Engineer, Minneapolis.
Saylor's	....	....	685	177	773	212	....	....	....	....	.....	City Engineer, Minneapolis.
St. Louis "Red Ring"	275	124	790	244	876	300	....	....	....	....	96	Washington University Laboratory.
Steel	128	55	405	224	511	278	....	....	72	127	98.47	City Engineer, Chicago.
Star	437	77	721	219	746	298	....	....	75	299	91.7	Board of Public Works, Philadelphia.
Shifferdicker (German)	272	....	446	175	590	....	....	....	....	....	86.9	City Engineer, Peoria, Ill.
"Sampson" (Canadian)	132	....	428	....	463	....	....	....	....	....	.....	City Engineer, Port Huron, Mich.
Sandusky	162	....	694	....	903	....	....	....	....	....	.....	City Engineer, Port Huron, Mich.
Stettin (Anchor)	....	....	471	168	630	255	....	....	....	....	.....	City Engineer, Youngstown, O.
Struthers	71	....	630	230	709	532	....	....	....	....	98.7	Pittsburg, Carnegie & Western R. R.
Scales (English)	171	....	622	212	795	268	....	....	....	....	99	U. S. Engineer, San Francisco.
Teutonia (German)	....	....	....	241	....	273	....	....	210	300	93.6	U. S. Engineer, San Francisco.
Thomas A. Edison	325	....	676	255	....	331	....	....	120	390	99.8	Lathbury & Spackman, Philadelphia.
Toltec (slag)	196	69	472	154	477	200	....	....	138	345	99	Department of Public Works, Philadelphia.
Universal	559	129	536	248	628	368	937	390	120	420	93.90	Robert W. Hunt & Co., Chicago.
Vulcanite	290	45	748	226	767	287	740	330	108	439	89.90	Board of Public Works, Philadelphia.
Victor ("Invincta")	372	....	486	170	562	226	....	....	....	....	95	Barber Asphalt Co., Long Island.
Wayland	187	42	456	220	565	337	....	....	78	240	88.4	City Engineer, Chicago.
Whitehall	328	79	855	339	991	459	....	....	180	360	95.75	U. S. Navy, Annapolis, Md.
White's (English)	....	....	356	....	268	110	256	122	15	45	94.03	Colorado Iron Co., Pueblo, Col.

AVERAGE TENSILE STRENGTH IN POUNDS PER SQUARE INCH OF VARIOUS NATURAL OR ROSENDALE CEMENTS.

Brand of Cement.	Twenty-four Hours.	Seven Days.		Twenty-eight Days.		Six Months.		Percentage thro'h No. 100 Sieve.	Test made by
	Neat.	Neat.	1 to 2.	Neat.	1 to 2.	Neat.	1 to 2.		
Akron Star-brand	172	259	......	352	......	475	......	......	City Cement Inspector, Philadelphia, Pa.
"Banner" Louisville	104	113	70	160	140	......	......	88	Chicago Drainage Canal Board.
Beaches	115	190	47	367	93	......	......	80	U. S. Engineer, Fort Delaware.
Ft. Scott "Double Star."	46	137	......	327	......	......	......	......	Manufacturer.
Improved Anchor	164	271	......	378	......	515	......	......	City Cement Inspector, Philadelphia, Pa.
Louisville Star	79	135	63	210	124	348	241	76.2	Osborn Engineering Co., Cleveland.
Lehigh Improved	145	235	......	352	......	440	......	......	City Cement Inspector, Philadelphia, Pa.
Milwaukee	97	141	......	259	......	397	......	93	Company's Laboratory.
Mankato	142	179	......	267	......	......	......	......	City Engineer, St. Paul, Minn.
Norton's Rosendale	107	141	36	......	......	......	......	......	Northern Central R. R. Co.
Northern Hydraulic	200	......	100	300	200	......	400	96	Manufacturer's guarantee.
Shield Improved	170	239	127	298	220	......	......	95	Booth, Garret & Blair, Philadelphia.
Utica	......	207	152	230	225	311	302	91	Sanitary District, Chicago.
Union Improved	155	209	......	316	......	446	......	......	City Cement Inspector, Philadelphia.

Mortar.—The following extract from an article on mortar was taken from the *Irish Builder:*

"Like all other compounds, mortar depends for its quality upon that of its constituents, and also upon the proportions in which they are used, and the method by which they are mixed. To all intents and purposes it is an exceedingly fine concrete, composed of an aggregate and a matrix mixed with water, its purpose being to fill up the interstices in the joints between the bricks or stones of which a wall is composed, so as to provide an even bedding surface, and render the wall water-tight, adherent properties being rather valuable for securing this than needed to prevent the bricks from being pulled apart.

"Thus it comes about that the more close is the jointing of a wall, the finer should be the grain of the mortar, and of its aggregate. A coarse rubble wall having wide, irregular mortar joints would be best with a mortar made of a fine gravel or crushed stone, or, at least, with one which contained a considerable amount of pea-sized lumps as well as finer sand amongst the aggregate, to assist in filling up the larger hollows without undue liability to settlement. On the other hand, for well-dressed ashlar masonry, the finest sharp-grained sand obtainable should be used, there being only very small cavities to fill up, and the very thinnest possible joint being required.

"Beyond this, it is necessary in all cases that the aggregate should, under a magnifying-glass, display either sharp edges or a roughened surface or both, in order that the matrix may adhere to it; for, while there is little necessity to stick the bricks of a wall together, if they be properly laid, it is quite necessary that the mortar should form in itself a homogeneous substance, else it will crumble into dust or wash out of the joints."

Lime Mortar.—Lime mortar is made by slaking the lime and adding sand in the desired proportion. The slaking is usually done by putting the lime in a water-tight box and covering with water. The lime is then stirred with the hoe so as to let the water get to all sides of the lumps of lime, and thus cause it to slake more readily. Enough water is added to make the mixture about the consistency of thick cream. It is then run off through a sieve into a larger box, where the sand is added and the mortar allowed to cool a little and thicken. The amount of sand used is regulated by the quality

of the lime used, as some limes will take more sand than others.

The "mortar-man" by experience can usually tell when he has enough sand added to the lime as he "runs it off," but if it is a little "rich," as it usually is, he will add more sand when he tempers it up for use. The mortar should have just enough sand in it to make it work nicely and not stick to the trowel.

The superintendent, by a little experience with, and watching, the mortar, will be able to tell at a glance if the mortar is "rich" or "poor." Mortar should be run off at least three days before using, so that the lime will have time to cool off and there will be no small particles of lime left unslaked and which may slake after being built in the wall.

Lime mortar should not be used in freezing weather, although if it is frozen hard and dry without any thawing it hardly ever affects it much, but, if it is alternately frozen and thawed, the mortar will lose its strength and be destroyed; so, to be on the safe side, it is well to follow the rule of using no lime mortar in freezing weather.

When the lime is being slaked the superintendent should see that it is of a good quality, as described on page 168, and that the sand is up to the requirements.

In making mortar for laying "press" brick or brick with a close joint, a fine white sand or marble-dust is generally used.

The New York Building Code requires that lime mortar be made of 1 part of lime and not more than 4 parts of sand.

Sugar in Mortar.—Sugar has been used for centuries in India in the making of lime mortar and is said to add greatly to its strength. Experiments were made some years ago to ascertain the effect of sugar on Portland cement, and an addition of from $\frac{1}{8}$ to 2 per cent of pure sugar added to Dyckerhoff's German Portland cement was found to considerably increase its strength after three months. The sugar was said to "retard its setting," and thus permit the chemical changes in the cement to take place more perfectly, but more than 2 per cent of it rendered the cement useless. As sugar is soluble in water it should never be used in mortar which is to be used under water.

Portland Cement-lime Mortar.[1]—"There are many kinds of work which require a quick-hardening mortar, but for which

[1] Extracts from "Das Kleine Cement-Buch."

the great strength of a mixture of 1 of cement with 1 to 4 of sand is unnecessary. The cost of such mortar is also for many purposes too high. A mixture of cement with 5 or more parts of sand would give abundant strength, but such mortars work too 'short' and adhere too imperfectly to the stone or brick; it cannot therefore be safely used. In such cases the addition of slaked lime or hydraulic lime will correct the faults of poor mixtures of cement and sand, and will produce a cheap mortar, suitable for a great variety of uses. Used in this manner, Portland cement may be used with economy for the most ordinary purposes. The advantages of Portland cement-lime mortar are its cheapness in comparison with other hydraulic materials, its rapid hardening, marked hydraulic properties, great strength on exposure to air, and remarkable resistance to weather.

"The following mixtures for cement-lime mortar have been found by experience to be most suitable:

Cement	1 part,	sand	5 parts,	lime paste	½ part.
"	1 "	"	6 to 7 parts,	"	1 "
"	1 "	"	8 parts,	"	1½ parts.
"	1 "	"	10 "	"	2 "

"The above proportions are to be taken by measure. Hydraulic lime may be used in the place of ordinary slaked lime.

"Cement-lime mortar is prepared by making a dry mixture of the required quantities of cement and sand; milk of lime is then made with the necessary quantities of lime paste and water and this milk of lime thoroughly mixed and worked in with the mixture of sand and cement."

In laying face brick in cement mortar it is advisable to add a little lime "putty" to the mortar, as it makes the mortar work smooth, and the mason can do a neater job. Mixtures of cement with three parts or more of sand are found to work too "short" for rapid and easy work in laying brick or stone. The addition of lime paste removes this defect, and makes the mortar smooth and plastic. The adhesion of the mortar to brick or stone, and also its impermeability to water, are also greatly increased by the addition of slaked lime. As to strength, it will be found that a mixture of Portland cement 1, lime paste 1, sand 6, is as good in every respect as a mixture of Portland cement 1, sand 3; or in other words, that one-half

the cement may be replaced by lime paste without loss of strength.

Compared with mortar made with Louisville, the Portland cement-lime mortar will be found immensely stronger, and little or no more expensive.

Cement Mortar.—In making cement mortar, the strength of it depends on the quality of the cement and sand, the proportions used, and the manner of mixing. The sand should be sharp and irregular, as described on page 168, the finest depending on the nature of the work in which the mortar is to be used.

For mortar for laying brick or for grouting, it should be comparatively fine, while for concrete or coarse mortar it should range from fine to coarse. A small amount of pure clay in the sand used for cement mortar will not affect its strength.

Proportions.—The proportions of cement and sand for cement mortar varies according to the cement used, and the strength of the mortar desired.

The most common mixture is 1 to 3 for Portland cement and 1 to 2 for natural cements. There must be enough cement to more than fill all the voids in the sand, and make a compact tree.

For masonry and brickwork, use 1 part cement to 2, 3, or 4 parts of sand, according to the strength required and the purposes for which the mortar is to be used; for some special purposes 5, or even 6, parts of sand may be used.

Cement mortar for face brickwork is usually composed of 1 part cement and 2 parts sand; for backing and in ordinary masonry foundations, it is not necessary to use a richer mortar than 1 part cement to 3 of sand. When large quantities of sand are used, the mortar is "short" and brittle, and will not work well.

In some cases lime paste is added to the cement mortar to give it the required plasticity. The proportions are about one-half part lime paste added to the mortar.

Stone dust and fine screenings have been used as a substitute for sand and gave as strong a mortar as if sand had been used. The table on page 171 shows the average strength of cement mortars of different proportions and age.

Water-tight Mortar.—For the lining of cisterns and reservoirs, and also in some cases for the protection of underground conduits and piping, a mortar which is impermeable to water

is required. According to Dykerhoff, the following mixtures will be found water-tight as soon as set:

Portland	cement,	1;	sand,	1:		
"	"	1;	"	2;	lime paste,	½.
"	"	1;	"	3;	" "	1.
"	"	1;	"	5;	" "	1½.

From the above mixtures the one may be chosen which offers the required strength and hardness.

A solution of 1 pound of concentrated lye, 5 pounds of alum, and 2 gallons of water mixed with cement in the proportion of 1 pint of the solution to 5 pounds of cement and applied with a brush and well rubbed in will make cement walls waterproof.

Mixing.—At the commencement of the work the superintendent should decide what shall be used as a unit of measure in making the mortar or concrete. The wheelbarrow is most commonly used, and if this is decided upon the superintendent should have a barrel of cement measured by the barrow so as to ascertain how many barrows of sand or aggregate are to be used to a barrel of cement.

The cement and sand should be put in the mortar-box dry and thoroughly mixed until they become a uniform color. The mass should then be drawn to one end of the box and the water added at the other end, and the mortar wet and mixed in just such quantities as can be used before the initial set begins. A common fault on most work is that the cement will be mixed up in large quantities in the morning and some of it will be four or five hours old before it is used. The superintendent should never permit any mortar over three hours old to be used, and any that attains this age in the mortar-box should be thrown away. He will not have to do this more than once or twice until the mortar will be made in such quantities as he desires. At night he should see that the mortar-box is left clean and if any mortar is not used have it thrown out to prevent it from being remixed again in the morning. He should also see that the mortar is mixed with just enough water to make it soft enough to allow the brick or stone to bed into it readily and fill all joints.

Coloring of Cement Mortar, etc.—The following coloring materials are usually used for coloring cement mortars. Usually coloring materials will lessen the strength of the mortars

so no more than necessary should be used; this is especially so of the ochres. To color

Gray, use 2 pounds of Germantown lampblack to a barrel of cement.

Black, use 45 pounds of manganese dioxide to a barrel of cement.

Blue, use 19 pounds of ultramarine to a barrel of cement.

Green, use 23 pounds of ultramarine to a barrel of cement.

Red, use 22 pounds of iron oxide to a barrel of cement.

Bright red, use 22 pounds of Pompeian or English red to a barrel of cement.

Violet, use violet oxide of iron 22 pounds to a barrel of cement.

Yellow and *brown*, use 22 pounds of ochres to a barrel of cement.

Ultramarine is one of the best coloring materials, as it does not affect the strength of the cement. Germantown lampblack is also good on account of the small quantity necessary to give a good color.

TEMPERATURE AND CEMENT.[1]—"The effect of cold is to stop the setting of cement. Most cements set very slowly, if at all, below a certain temperature, which is usually between 30° and 40° F. When the temperature is raised the cement sets, unless in the mean time the water has evaporated sufficiently to leave an insufficient quantity for the chemical action, so that the freezing of work laid in cement mortar usually has the effect simply of delaying the hardening of the mass. If too much water is used in the mortar, the expansion of the water in freezing may disintegrate the mortar by the mechanical action of the ice in forming. Either of these effects is most apparent near the surface of the mass of masonry, and often requires pointing up of the joints of brick or stone masonry, while the remainder of the work will be found in good condition. Alternate freezing and thawing increases the danger of injury. Portland cement is seldom injured by freezing, but many natural cements are more or less injured, and mortar of natural cement is the more liable to disintegrate even under the best conditions if the temperature is long enough or often enough below freezing-point before it has had an opportunity to set. In a few instances some setting of mortar frozen for a long time has been observed, but as a rule the setting is delayed until the temperature again

[1] *National Builder.*

rises above the freezing-point. The first method of aiding the setting of mortar which suggests itself is to delay the time of reaching the freezing-point by heating the stone or brick, the sand, the cement, and the water. The amount of heat required depends upon the temperature of the air and the rapidity with which the work can be done after heating stops. This method is seldom entirely satisfactory unless very quick-setting cements are used. Slow-setting cements will evidently give more trouble than those which set as quickly as can be permitted under the conditions of time necessary to get the mortar into the work after the water is added. Mortar should be made richer than for use at ordinary temperatures, say one to one and a half, instead of one to two, and other mixtures in the same proportion. As little water as possible should be used, although this will increase the probability of requiring pointing of joints or the crumbling of outer surfaces of concrete. It is frequently possible to delay freezing by covering the work with straw or even tarpaulins. If stable manure can be kept in place in sufficient quantities to keep up its fermentation it is the most efficient material for covering. Perhaps the most common method of preventing the freezing of mortar is the use of a solution of common salt for mixing. The usual rule is to add 1 per cent of salt to the water for every degree of temperature below freezing, using the minimum temperature to which the masonry will be subjected for the computation. The cold delays the setting of the cement, but there is no mechanical action from freezing, and the results of this method are usually quite satisfactory, the pointing of joints being the only additional operation expected. It is evident that work to be placed upon concrete laid in freezing weather must be delayed until the setting of the cement makes the mass sufficiently stable to carry the weight. Laying of masonry, especially of massive stone masonry, in freezing weather is quite easy, but the placing of masses of concrete in exposed situations, or of small sections of concrete, is not so easy nor so certain of success."

The author has used mortar and concrete made of Portland cement in freezing weather and never experienced any trouble, the mortar or concrete made and used in cold weather being equal in strength in a few months to that made in warm weather. The main point in using cement mortar or concrete in freezing weather is to not use too much water, and to keep it from freezing until it is well set.

Natural cements should not be used in freezing weather, as they will not stand freezing.

Sidewalks should not be laid or any plastering or finishing done with cement in freezing weather; the finished surface may be affected by the moisture in the mortar freezing and expanding, causing blisters, making the finished surface scale off.

In using cement in hot weather, where the heat or the rays of the sun will strike it, care must be taken to protect it, for heat in such cases dries the cement too quick, drawing out the water before the proper action of the cement takes place, and thus decreasing its strength to a great extent. The small cracks like those in dry mud, sometimes seen in pavements, are the results of the cement being dried too fast by the heat.

When laying sidewalks, plastering walls, pointing or finishing any surface with cement, it must be well protected from the heat, and should be wet two or three times a day for about four days after being laid.

The following paper, by C. S. Gowen, M. Am. Soc. C. E., giving the result of experiments made by him while resident engineer of the New Croton Dam, N. Y., was read before the Cement Section of the American Society for Testing Materials, July 3, 1903:

Tests of Portland-cement Mortar Exposed to Cold.—The following experiments were made with a view to getting some definite information on the effect of frost on Portland-cement mortar, under the different conditions in which it may be desired to use it in cold weather. No facilities existed for maintaining a prolonged cold or uniform temperature and the briquettes were accordingly exposed to the open air, and so kept until it was evident that the tendency to "dry out" unduly was reducing their proper strength and creating a condition by which no basis of comparison with ordinary results could be had.

The briquettes were accordingly placed in water in July, at the end of the first six months of the tests, and the author is inclined to the opinion that if this had been done earlier, at the end of the three months' tests, the twelve months' results would have showed much nearer the average twelve months' results of tests made in the ordinary way of briquettes kept

BREAKING WEIGHTS OF 2 : 1 MORTAR BRIQUETTES, POUNDS PER SQUARE INCH, EXPOSED TO COLD AT NEW CROTON DAM.

(Cement used, Giant Portland; sand used, crushed quartz—Lot 209, 1476 bbls. Each breaking weight given is the mean of eight breakings.)

Temperature Intended.		Twenty-eight Days.		
		Breaking Weight, Pounds per Square Inch.	Temperature Exposure, Degrees.	Time to Take Heavy Wire.
24 to 32°	....	370	22 r.	4 hrs.[2]
24 to 10°	....	458	24 f.	Night
24 to 32°	....	371[1]	28 f.	65 min.
20 to 10°	....	272	16 r.	6 hrs.
20 to 10°	....	255	18 s.	35 min.
24 to 32°	Three months	474	27 r.	4½ hrs.[2]
24 to 10°		455	22 s.	Night
24 to 32°		413	28 f.	65 min.
20 to 10°		360	16 f.	4 hrs. r.*
20 to 10°		246	18 s.	35 min.[3]
24 to 32°	Six months	366	34 f.	....
24 to 10°		347	12 r.	15 min.[3]
24 to 32°		314	28 f.	65 min.
20 to 10°		287	14 r.	2¾ hrs. r‡*
20 to 10°		300	18 s.	35 min.[3]
24 to 32°	Nine months	553	28 r.	4½ hrs.[2]
24 to 10°		381	14 r.	15 min.[3]
24 to 32°		452	28 f.	65 min.
20 to 10°		567	20 r.	5½ hrs.†
20 to 10°		437	18 s.	35 min.[3]
24 to 32°	Twelve mos.	553	26 r.	7 hrs. s.
24 to 10°		586	16 r.	45 min.[4]
24 to 32°		510	28 f.	45 min.
20 to 10°		602	26 f.	2½ hrs.[3]*
20 to 10°		512	16 s.	35 min.[3]

[1] This set was broken on a day when the temperature was 16°; a ninth briquette was thoroughly thawed on same day and broke at 210 pounds.

[2] Did not appear frozen when it took heavy wire.

[3] Frozen at end of time noted, and took wire.

[4] Froze slowly and took heavy wire.

* Had not set at end of time noted.

† Some signs shown of freezing.

‡ One briquette made with fresh water froze and took heavy wire in 20 minutes.

Remarks.—24 to 32°: Placed in cold air at temperature noted immediately after mixing; fresh water used. 24 to 10°: Placed in cold air at temperature noted immediately after mixing; fresh water used. 24 to 32°: Took heavy wire before being placed in cold air; fresh water used. 20 to 10°: Placed in cold air at temperature noted immediately after mixing; brein used. 20 to 10°: Placed in cold air at temperature noted immediately after mixing; fresh water used. In column of "Temperature Exposure" r. indicates a rising temperature, f. a falling temperature, and s. a steady temperature. All briquettes were left in open air in a dry but not sunny place until the three months' break was made (about April 15); then they were put in a damp place until the six months' break was made (about July 15); and then they were placed in water until finally broken. The brine used was a solution strong enough to float a potato, about 10 per cent by weight of salt to weight of water.

in water continuously until broken. In the table given below each breaking weight given is the mean of eight briquettes broken, and it may be said that each set of breakings showed marked uniformity in the strength of the briquettes.

AVERAGE BREAKING WEIGHTS OF 2 : 1 MORTAR BRIQUETTES. GIANT PORTLAND CEMENT, BROKEN AT NEW CROTON DAM IN 1896, 1897, 1898.

		Lot 209, 1476 bbls.
Time	28 days	...
Number of breakings	690	10
Average breaking weight, pounds per square inch	441	483
Time	3 mos.	...[1]
Number of breakings	215	...
Average breaking weight, pounds per square inch	563	...
Time	6 mos.	...
Number of breakings	185	...
Average breaking weight, pounds per square inch	657	...
Time	9 mos.	...
Number of breakings	155	...
Average breaking weight, pounds per square inch	671	...
Time	12 mos.	...
Number of breakings	165	...
Average breaking weight, pounds per square inch	663	...

[1] Normal test of this lot not continued after 28 days. Time of taking heavy wire, mean of seventy tests (2 : 1), briquettes, 63 min.; mean of seventy tests, neat briquettes, 71 min.; average breaking weight, mean of seventy tests (2 : 1), briquettes, 1 week, 344 pounds.

The results are from experiments made by the author while acting as resident engineer for the Aqueduct Commissioners of the City of New York, in charge of the New Croton Dam, and to them the author wishes to make proper acknowledgment for the use of these data.

Effect of Cold upon Setting.—In the case of this lot of cement, which was moderately quick-setting (taking heavy wire in sixty-three minutes, 2 to 1 briquettes, and taking heavy wire in seventy-one minutes, neat briquettes, under normal conditions of testing in laboratory), moderate cold, 22° and upward, delays setting but does not freeze. This is shown by the set of tests made for the intended temperature, 24° to 32°, of exposure.

The second set of tests (intended temperature of exposure 24° to 10°) show in the case of the twenty-eighth day and three months' breakings (temperature 24° and 22°, respectively) a

delayed setting which resulted in freezing during the night. The other breakings, six, nine, and twelve months, show, at lower temperatures, quick freezing.

The third set of tests (intended temperature of exposure 24° to 32°) was exposed to moderate cold after having taken heavy wire in laboratory.

The fourth set, a mixture with brine (intended temperatures of exposure 20° to 10°), shows clearly the influence of the cold in delaying the set, as well as the effect of the brine in delaying freezing.

At temperature of exposure 16° +, the set occurred in six hours; 16° −, no set in four hours and no sign of freezing; 14° +, no set in two and three-quarter hours and no sign of freezing; 20° +, a set in five and one-half hours with some indications of freezing; 26° −, no set in two and one-half hours and no sign of freezing.

The fifth set of briquettes was exposed at a steady temperature of 18° ±, and all froze in thirty-five minutes.

Conclusion.—A moderately quick-setting cement can be used in temperatures about 20°, without freezing, with a 2:1 mixture.

The use of brine delays freezing, at least at temperatures of about 15°, if it does not wholly prevent it before the set has occurred.

Effect of Cold upon Beaking Strength.—It is apparent that the general falling off at the end of six months is due to air exposure, the rise for nine and twelve months after being placed in water being marked, and the author is of the opinion that had briquettes enough been made for fifteen and eighteen months' breakings there would have been a uniform increase in strength, comparing favorably with general results from laboratory tests, a summary of which has been added to the tabular statements. The six months' breakings of the various sets show a much greater uniformity than those of one month and three months, as might have been expected, the extremes being 287 and 366 pounds.

At nine months sets 1 to 4 agree closely,
" " " " 3 to 5 agree closely,

while set 2 is lower in its breaking weight than either of the others.

At twelve months sets 2 to 4 agree closely,
" " " " 3 to 5 agree closely,

while set 1 comes between these extremes, which vary between 510 and 602 pounds, an extreme variation, not much greater than indicated by the six months' breakings, and much less than that shown by the nine months' results.

Conclusion.—The general result is favorable to the use of brine at low temperatures; also there is no indication that freezing reduces the ultimate strength of the mortar, although it delays the action of setting.

In this particular example the frozen set No. 2 shows better at twelve months than frozen set No. 5, but not so well at nine months, where the relative difference is the other way.

At twelve months sets Nos. 2 and 4 ("frozen at low temperature" and "brine") agree closely.

Set No. 1 comes next ("mixed at moderate temperature"), and sets Nos. 3 and 5 follow.

There seems to be nothing in the results shown in set No. 3 to indicate an advantage in securing a set before exposure to freezing temperature.

The above results are relative rather than conclusive, as it is impossible to say what would have been the results at the end of the year, and how they would have compared with the general average given for briquettes tested under normal conditions if they had not been exposed to the varying temperatures of spring and early summer and to "drying out."

These briquettes were mixed in February, 1897, as opportunity and the required temperatures occurred, and the records of the time of setting were made as carefully as was practicable under the circumstances.

The temperatures of the air at the time of the final test for the set were not taken, but as a rule the temperature rose or fell, as indicated, steadily during the time that elapsed while the observation was made. These results are submitted for what they may be worth, as the author does not know of any series of tests extending over so long a time and at the same time covering such extremes and variations of temperature.

The following, showing the results obtained by tests made under ordinary laboratory conditions, when brine was used, are added here, and the conclusion seems to be plain that the effect of brine is to delay setting temporarily, while not affecting the ultimate strength of the mortar materially.

Giant Portland 2 to 1 briquettes.

Per cent of water used to weight of cement, 40.

Time to take heavy wire, fresh-water briquettes, 241 minutes; salt-water briquettes, 306 minutes.

	One Week.	One Month.	Three Months.	Six Months.	Nine Months.	Twelve Months.
Fresh water used......	236	289	414	549	554	572
Salt water used	126	231	294	424	452	576

Giant Portland 3 to 1 briquettes.

Per cent of water used to weight of cement, 50.

Time to take heavy wire, fresh-water briquettes, 350 minutes; salt-water briquettes, 407 minutes.

	One Week.	One Month.	Three Months.	Six Months.	Nine Months.	Twelve Months.
Fresh water used......	112	183	268	335	351	458
Salt water used	68	131	215	266	301	413

Standard sand used (crushed quartz).

The brine used was strong enough to float a potato, about a 10 per cent solution by weight.

Each of the above results is the mean of ten breakings, in pounds per square inch.

The briquettes were placed in air twenty-four hours and then immersed in water until broken.

The following shows the result of tests for freezing and thawing of cement, made by H. W. Parkhurst, Engineer of Bridges and Buildings, Illinois Central Railroad Company.

"Briefly described, these were made as follows: Sets of briquettes were made, one-half of which were put on the flat roof of our office-building, where they were exposed to all the changes of weather, commencing in December, 1902. The other half of the briquettes were treated in the usual way-being put in pans of water kept at pretty nearly uniform tem, perature (between 60 and 70 degrees F.), and sets of ten were taken from each of these lots at the age of twenty-eight days, two months, three months, four months, five months, and six months. Column headed "Frozen" contains results of those that were out of doors exposed to the weather. Column headed

"Warm" shows results of those that were kept in the house at uniform temperature. The column headed "Per Cent" shows percentage of strength of briquettes exposed to freezing as compared with those of the same date and age which were not so exposed. You will note that in the case of the "one-to-three" mortar, the briquettes that were exposed to the weather came out considerably stronger at four, five, and six months' age than those which were kept in the water all the time. This speaks well for the probable condition of concrete under the usual exposure."

The freezing and thawing tests are shown in the following tabular statement:

AA PORTLAND CEMENT—1902–1903.

FREEZING AND THAWING.

Sieves: No. 50, 100 per cent; No. 100, 99.8 per cent.

Age.	One to Two.				One to Three.				Remarks.
	Date Brok'n 1903.	Frozen	Warm	Per Cent.	Date Brok'n 1903.	Frozen	Warm	Per Cent.	
28 days	1/23	233	425	55	......	189	290	65	1/27
2 mos.	2/26	334	535	62	2/28	259	348	74	2/28
3 mos.	3/26	363	572	63	3/30	331	381	87	..
4 mos.	4/26	395	595	66	4/30	453	325	139	..
5 mos.	5/26	462	611	76	5/30	441	373	118	..
6 mos.	6/26	628	531	118	6/30	563	363	155	..

Grouting.—Grout is a thin mortar usually made of sand and cement, and is generally used in brickwork, by building up the two outside courses of the wall, then laying the inside brick and pouring the thin mortar over them, working it well into all the joints. The grouting should be done every course, so that all the joints will be filled.

Brick wet and laid with ordinary mortar and the mortar slushed into all the joints makes just as strong a wall as grouting, but because it is hard to get brick-masons to lay brick as they should be, grouting is often resorted to when a strong wall is desired.

Concrete.—Concrete is a mixture composed of broken stone, gravel, or similar material held together by cement mortar. The theory of concrete is that enough cement mortar should be used to fill all the voids between the stones.

On large engineering works, the proportions of cement, sand, and broken stone or gravel should be accurately determined

and specified. For general purposes it is possible to state approximate proportions, as the sand, broken stone, and gravel vary in size and proportions of voids according to their source and preparation.

The proportion of sand and stone must also be adapted to the character of the work in which the concrete is to be used and the strength required. The superintendent can tell when the first batch of concrete is rammed in place if the proportions of mortar and aggregate are such that the concrete will ram well and all the voids will be filled solid.

Concrete is being used more and more every day and is now one of the most used building materials, and as it is one most easily slighted, will require the closest attention from the superintendent. When any concrete work is being done the superintendent should be present at all hours while the work is in progress, and see that each batch of concrete is made of the correct proportions and mixed thoroughly, and that it is put in place as soon as mixed.

Any time he sees any of it slighted he should reject it at once, or have it mixed over. He should also see that no concrete is used after initial set has commenced; any concrete over three hours old should be rejected.

WET AND DRY CONCRETE.—There is quite a difference of opinion among engineers and architects as to just what amount of water should be used in mixing concrete to get the best results. Some claim that it should be mixed with as little water as possible, others think that a very plastic or wet concrete is best. It is the opinion of the author that either according to the conditions under which it is to be used is better than the other. For instance, in a large foundation or any place where the concrete can be spread in thin layers and where no trouble will be experienced in ramming, a mixture that when rammed enough to make it a solid and compact mass with no voids, and which at the end of this ramming shows just a little water at the top, will make as good a concrete as it is possible to obtain. On the other hand, in narrow walls or foundations, between beam grillage, and all places where any difficulty will be had in ramming, then a wet concrete will work the best.

The author has used concrete in such places, mixed so it would just carry the man ramming, and which when he walked or tamped on it, caused it to "quake," which gave excellent results, and contained no cavities. Where a concrete is to be

made water-tight a mixture of this kind will give the best results.

Tests have been made which show while the dry concrete becomes much stronger in a short period of time, the wet mixture if allowed to harden for a long period will ultimately become stronger than the dry mixture.

The superintendent must decide, according to the work to be done, just how wet the concrete should be mixed, and he can determine this after a little of it has been put in place and rammed.

Where a wet concrete is to be used the forms or moulds should be nearly water-tight.

Mixing Concrete.—This is another point in concrete work where engineers and architects differ in opinion, some even preferring hand-mixing to that done with a machine. There are a number of ways or methods employed for mixing concrete by hand, and they will nearly all give good results providing enough labor is expended.

This is where the contractor usually tries to save a little, turning the mass once or twice, when it should be turned four or five times. Then experience is a factor in turning concrete by hand; a man who has had experience in turning will mix better with two or three turnings than a man with no experience will do in four or five. It is the duty of the superintendent to examine the first batch after it is mixed and see if it is satisfactory; if not, he should have it turned and mixed until it is, and then see that all subsequent batches are mixed the same.

It is well to let the contractor use his own method of mixing provided it gives the desired results.

A method which the author has used for hand-mixing and which gave excellent results as to cost of labor and result of mixing is subjoined:

Make a tight platform about 30 feet long and 14 feet wide. On one end of this platform mix the sand and cement dry in the following manner: Have a bottomless box of sufficient size and depth to measure the exact proportion of sand, place it on the platform as shown at *A*, Fig. 123, and fill it with sand, using a straight-edge to strike it level full. On top of this set another bottomless box of the correct depth to measure the correct proportion of cement and fill it in like manner; now lift the two boxes and thoroughly mix the sand and cement until it is of a uniform color.

While the cement and sand are being mixed by part of the "gang," let the rest prepare the aggregate. Place a bottomless box on the platform close to the pile of cement and sand as shown by *B*, Fig. 123, the box to be of a depth to measure the

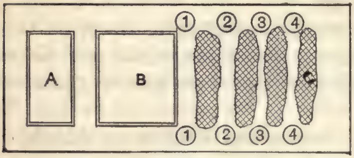


FIG. 123.

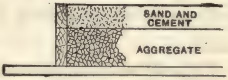


FIG. 124.

aggregate; fill it level full and set on top another box to measure the combined cement and sand; fill this box level full, as shown by Fig. 124; now remove the boxes and the mass is left in a flat pile with the cement and sand spread uniformly over the aggregate. Now let two men, as 1, 1, Fig. 123, start turning the pile toward the vacant end of the platform, and as they turn keep the new pile about the same width and depth as the one made by the boxes.

After they have started turning start two more men as shown at 2, 2, giving the second turning; but as it is turned and spread in the pile have a man with the hose and sprinkler (or a good plan is to tie the nozzle of the hose on a shovel-blade so the blade will spray the water) and wet the mass as it is spread in the pile. Then give it two more turnings by men at 3, 3 and 4, 4, and when it reaches the pile *C*, as shown in Fig. 123, it is thoroughly mixed. With a little experience the man with the water will be able to regulate it so that each batch will have about the same amount of water.

The author has also used three boxes as described, on top of each other, one for the aggregate, one for the sand, and one for the cement; then turning and mixing the mass as described, it gave a very uniform mixture. In mixing by hand the men should be provided with long-handled, square-bladed shovels, as they can reach the centre of the pile better and will not tire themselves as with a short-handled shovel. In large work the concrete can be mixed very rapidly as described; as one batch is being finished another one can be got ready, and thus a continuous stream of concrete can be turned out. The author has seen concrete mixed in this way in competition with a

machine where the amount mixed by hand in a day was equal to that done by the machine with the same amount of labor.

On small work where it would not pay to go to the trouble as described above, a good method is to mix the sand and cement dry, then add the water, making a wet mortar; spread this out and add the aggregate which has already been wet and washed; now turn and mix until a uniform mass is obtained.

Where machine-mixing is done, the superintendent must see that the proper proportions are used, and it is well for him to have the sand and cement mixed dry by hand before going into the machine. Some machines are so arranged with a spiral feed that they are supposed to feed themselves. When a machine of this kind is used, the superintendent should have a batch of concrete measured out in the desired proportions and run through the machine to see if it feeds correctly. After the concrete comes through he should examine it and see if it is thoroughly mixed and if too wet or dry. If not mixed right, he should have it run through again or mixed by hand.

AGGREGATE.—The aggregate for concrete is usually broken stone, gravel, or cinders, or two or all of them combined. Along the seashore and rivers gravel is often used because it can be obtained much cheaper than the broken stone, and makes very good concrete, but on account of the smooth surface of the stones does not make quite as strong a concrete as broken stone, which with its rough angular surfaces and corners causes the mortar to take a better hold.

Broken stone from ½ to 2 inches makes the best concrete and does not require quite as much mortar, the voids not being so large as if the stone were all of the 2-inch size.

Cinder aggregate is usually used for fireproofing of floors, etc.

When broken stone is used it should be cleaned from dust and dirt, by passing it over a ⅜-inch mesh sieve.

Gravel can usually be cleaned by washing it to take out the clay or earthy matter. It should vary from ¼ to 2 inches in size.

Cinders for concrete should be nearly all clinkers which will pass through a 1-inch mesh sieve, and if very dirty, they should in addition be passed over a ⅜-inch mesh sieve. They should not contain more than 5 per cent of ash or unburned coal. Specifications usually call for rolling-mill slag or good,

clean, crushed vitrified clinkers, and the superintendent should see that such material is used, as the ordinary cinders are not fit for fire-proof work.

CRUSHED STONE should be clean and free from dust or dirt, and should not exceed 1½ to 2 inches in size. The best results are obtained from strong, hard, durable rocks, with fracture into sharp angular fragments, such as trap-rock or limestone. Soft, porous, friable rocks, or rocks of a slaty fracture, should be avoided. For some purposes certain kinds of slag make an excellent concrete. Dust in crushed stone weakens the concrete. The best concrete is obtained from crushed stones of various sizes. In some cases the stone is screened to separate the different sizes, which are then remixed in the proper proportions.

SAND FOR CONCRETE.—Sand should be clean, coarse, and sharp. A quartz sand gives the best results. Loamy sand or that containing much clay should not be used; it will give poor results and retard the set. Organic matter and dirt are objectionable in any sand. A very fine sand or gravel is not good, as it weakens the work. A very coarse sand gives the greatest strength in concrete, but when the proportions of sand exceed 2 parts to 1 of cement, a sand of mixed grains, fine to coarse, with the coarse predominating, is preferable, as the fine sand helps to fill the voids in the coarse sand and makes a more dense and less absorbent mortar.

PROPORTIONS AND STRENGTH.—The proportion of the mortar to the aggregate should be such that it will a little more than fill all the voids of the aggregate, the strength of the concrete depending a great deal on the proportion of sand to the cement.

For all ordinary purposes, such as heavy foundations, machinery foundations, reservoirs, cisterns, retaining-walls, sub-surfaces of sidewalks, cellars, and street-paving, 1 part of cement, 2 or 3 parts of sand, with 5 parts of broken stone, will give the best results; for footings and subwork 1 part of cement, 3 parts of sand, and 7 parts of broken stone will give excellent results.

The superintendent should see that the proportious are such that the mortar will fill all the voids in the aggregate, and the mass will tamp solid. The proportion of cement and sand to the aggregate depends a great deal on the nature of the aggregate; if it is of coarse stone with large voids then it will require more mortar to fill them than if the aggregate was of a

finer stone or gravel. To determine the voids in any aggregate, take a box containing a cubic foot and fill it with the aggregate, which should already be soaked with water, then pour water in the box until it is full; now pour off the water and measure it, which will show the voids contained in a cubic foot of the aggregate.

A good method of determining the voids in concrete materials is to fill a box of exactly 1 cubic foot capacity, or a convenient fraction thereof, with the substance and weigh the contents. A solid block of quartz or limestone, measuring exactly 1 cubic foot, will weigh 165 pounds; a cubic foot of sand, gravel, or broken stone, considerably less: and the difference will represent the voids. For example, if 1 cubic foot of gravel weighs 95 pounds, the difference is $165-95=70$. The percentage of voids is then $70\times100\div165=42.4$.

The following table shows the percentage of voids found in some common concrete materials:

Sand, not screened..........	32.3	per cent	voids
Gravel, $\frac{1}{4}$- to $\frac{1}{8}$-inch..........	42.4	"	"
Broken stone, 1- to 2-inch....	47.0	"	"

Mixed materials, which contain the greatest variety of sizes from fine to very coarse, will be found to have the least voids. With any two materials, one fine and one coarse, there is one mixture, and only one, which will give the greatest possible density. This may be determined by calculation; for example, taking the gravel given above, since it contains 42.4 per cent voids, we must fill these by adding sand to the amount of 42.4 per cent of its volume. For this we require 42.4 measures of sand to 100 measures of gravel, or 1 to $2\frac{1}{3}$. For the stone, 47 measures to 100 will be required, or 1 to 2.13. With mixed materials, such as are generally met with in practice, in which no sharp division between sand and gravel can be made, practical test will be found more satisfactory than calculation. The sand and gravel or stone should be mixed in the calculated proportion, and also in other proportions, and the weight per cubic foot of each mixture taken, until that giving greatest density is found. With favorable materials it will be found possible to make a mixture weighing 140 pounds per cubic foot, corresponding to 15 per cent voids. If the greatest weight obtainable is less than this, the materials are not the best.

The proportion of cement to be used depends upon the per cent of voids in the mixture of sand and gravel or stone, and also upon the purpose for which the concrete is required. In general it may be said that an amount of cement sufficient to fill the voids in the mixture will give a first-class concrete. With mixed materials weighing 140 pounds per foot and containing 15 per cent voids, cement to the amount of 15 per cent, by measure, or 1 to $6\frac{2}{3}$, will theoretically be required. Greater compression strength may be obtained by increasing the proportion of cement, and for the foundations of engines or other heavy machinery as high a proportion as 1 to 5 may well be used. On the other hand, for foundations of buildings, filling of abutments, and other purposes requiring less strength, mixtures of 1 to 10 or 1 to 12 will be found fully satisfactory.

It should be remembered that the strength of the concrete will depend on its density. A mixture of cement and sand, 1 to 3, will usually be found weaker than a 1 to 7 mixture, rightly proportioned, of cement, sand, and gravel or stone. Mixtures of cement and sand are greatly *strengthened* by the addition of a suitable amount of coarse material, though the proportion of cement is thus decreased. It is, therefore, well worth while to give careful study to the concrete materials which it is proposed to use.

The following table, showing the result of tests of cement mortar of different proportions and age, was made at the United States Arsenal, Watertown, Mass. The cement used was Peninsula Portland cement.

COMPRESSIVE STRENGTH OF PORTLAND-CEMENT MORTAR IN POUNDS PER SQUARE INCH.

Age in			Neat.	1 Cement, 1 Sand.	1 Cement, 2 Sand.	1 Cement, 3 Sand.	1 Cement, 4 Sand.
Air.	Water.	Air.					
7	......	......	4970	2350	1370	....	473
1	6	......	6260	2380	1440	....	557
30	......	......	6140	3400	1490	....	656
1	29	......	8870	4680	2750	....	950
92	......	......	6080	3410	....	....	....
1	91	......	9560	....	....	....	....
1	91	2	....	7570	....	....	....
1	90	2	....	....	4990	....	....
93	......	......	....	....	2635	....	....
100	......	......	....	....	....	....	1030
101	......	......	....	....	....	1510	....
1	96	4	....	....	....	3140	....
1	95	4	....	....	....	....	1970
1	70	......	....	....	....	2570	....

The following tests of the tensile strength of Portland-cement mortar of different proportions and age were made by the New York State Canal Commission. The cement used was Glens Falls "Iron Clad."

NEW YORK STATE CANALS.

DEPARTMENT OF CEMENT TESTS.

Record of cement tests made with the Glens Falls "Iron Clad" Portland cement, showing tensile strength in pounds per square inch. All briquettes kept in air twenty-four hours, balance of time in water. Figures below represent in each case the average of five briquettes. Quartz was used in mixing all briquettes.

Kept in Water.	Amount of Water Used.					
	2½ oz.	1½ oz.	1½ oz.	1½ oz.	1¼ oz.	1 oz.
	Proportions Used in Mixing.					
Number of Days.	Neat.	1 Sand, 1 Cement.	2 Sand, 1 Cement.	3 Sand, 1 Cement.	4 Sand, 1 Cement.	5 Sand, 1 Cement.
6	516	549	237	210	162	133
12	609	569	349	242	186	150
18	651	651	423	267	222	169
24	671	660	435	277	227	169
30	715	665	446	285	233	171
Number of Months						
3	776	714	549	347	225	184
6	784	651	540	441	217	189
9	744	742	490	375	259	202
12	764	714	535	380	287	194
15	836	738	536	395	292	204
18	848	775	576	396	271	216
21	920	789	555	411	298	238

(Signed) HERSCHEL ROBERTS,
Deputy State Engineer and Surveyor.

The following tests as to the tensile strength of natural-cement mortar were made with the "Improved Shield" brand of Rosendale cement:

		Neat Cement.	1 Cement, 2 Sand.
Tensile strength in	24 hours	118 lbs.	......
" " "	3 days	161 "	......
" " "	7 "	204 "	142 lbs.
" " "	30 "	318 "	278 "
" " "	60 "	374 "	352 "
" " "	90 "	398 "	418 "
" " "	180 "	440 "	500 "
" " "	360 "	501 "	568 "

The following tests on the crushing strength of concrete were made by Lathbury & Spackman, Philadelphia, Pa.

REPORT ON CRUSHING STRENGTH OF SIX-INCH CUBES.

Composition.	Age.	Average Crushing Strength, Three Cubes to Each Test.
1 part Lehigh Portland cement. 2 parts sand. 4 parts crushed stone.	7 days 30 " 90 "	36,270 lbs. 85,810 " 98,087 "
1 part Lehigh Portland cement 3 parts sand. 6 parts crushed stone.	7 days 30 " 90 "	28,433 lbs. 62,003 " 73,073 "
1 part Lehigh Portland cement. 4 parts sand. 8 parts crushed stone	7 days 30 " 90 "	22,687 lbs. 48,790 " 61,230 "

The following report of U. S. Engineer Corps gives the result of tests made with Atlas Portland cement in concrete of different proportions.

OFFICIAL REPORT U. S. GOVERNMENT ENGINEERS ON ATLAS PORTLAND CEMENT.

REPORT OF TESTS OF CRUSHING STRENGTH OF ONE-FOOT CUBE OF CONCRETE.

Made by Capt. Wm. M. Black, Corps Engineers, U. S. A., Washington, D. C., Dec. 1, 1897.

No.	Composition.	Age.	Crushing Strength.
7	1 part Atlas cement 2 parts sand 6 parts broken stone	10 days 2 months 6 " 12 "	137,500 lbs. 255,000 " 320,000 " 440,000 "
11	1 part Atlas cement 2 parts sand 3 parts gravel 3 parts broken stone	10 days 2 months 6 " 12 "	95,000 lbs. 232,500 " 280,000 " 405,000 "
8	1 part Atlas cement 2 parts sand 2 parts gravel 4 parts broken stone	10 days 2 months 6 " 12 "	32,500 lbs. 267 500 " 295 000 " 390,000 "

The following are the requirements of the U. S. Navy for tensile tests of Portland cement.

TENSILE STRENGTH.—The neat briquettes, prepared as specified, shall stand a minimum tensile strain per square inch, without breaking, as follows:

For 12 hours in air and 12 hours in water				.... 200 lbs.
" 1 day	" "	" 6 days	" "	.... 550 "
" 1 "	" "	" 27 "	" "	.... 650 "

The mortar briquettes, prepared as specified, shall stand a minimum tensile strain per square inch, without breaking, as follows:

After 12 hours in air and 12 hours in water				.... 150 lbs.
" 1 day	" "	" 6 days	" "	.... 200 "
" 1 "	" "	" 27 "	" "	.... 250 "

CRUSHING STRENGTH OF NATURAL-CEMENT CONCRETE.—Report of crushing tests made by the U. S. Government at the Watertown Arsenal, Watertown, Mass., of concrete blocks made with Akron Star Brand Natural Cement, the blocks being cubes, 12 inches each way, thus making each block one cubic foot of concrete. The strength given is the average of three blocks of each kind.

Cement.	Sand.	Gravel.	Broken Stone.	Thirty Days, Lbs.	Seven Months, Lbs.	One Year, Lbs.
1 part	1½ parts	0 parts	4 parts	215,835	321,833	432,333
1 "	3 "	0 "	7½ "	150,367	290,167	306,667
1 "	2 "	3 "	4 "	161,200	319,867	329,500
1 "	2 "	7 "	0 "	110,267	239,533	264,700
1 "	2¼ "	8 "	0 "	109,467	225,733	232,733

PROTECTION OF STEEL BY CONCRETE.—By tests made, it has been found that steel or iron when properly covered with cement mortar or concrete is perfectly protected from rust, but the mortar must have contact with and cover all surfaces of the steel. The concrete should be made wet enough so that it can be tamped close around the steel. With cinder concrete it should be thoroughly mixed and wet enough so that the cinders will not absorb all the water before the cement is tamped in place.

The following conclusions were arrived at by Mr. C. L. Norton after making a number of tests as to the value of cement mortar and concrete to protect steel from rust:

"(1) Neat Portland cement, even in thin layers, is an effective preventive of rusting.

"(2) Concretes to be effective in preventing rust must be dense and without voids or cracks. They should be mixed quite wet when applied to the metal.

"(3) The corrosion found in cinder concrete is mainly due to the iron oxide or rust in the cinders and not to the sulphur.

"(4) Cinder concrete, if free from voids and well rammed when wet, is about as effective as stone concrete in protecting steel.

"(5) It is of the utmost importance that the steel be clean when bedded in concrete. Scraping, pickling, a sand-blast, and lime should be used, if necessary, to have the metal clean when built into a wall."

Fred. von Emperger, C.E., describes rods embedded in concrete under water for four hundred years coming out free from rust. W. G. F. Triest dug a wrench out of a concrete bridge pillar, which was free from rust after being embedded for twenty-two years. E. L. Ransome partly embedded some hoop iron in concrete blocks and left them exposed to sea air for many years. When the exposed iron had disappeared in rust, the blocks were cut open and the iron was found to be free from rust. The safety of the Chicago buildings supported by steel grillages depends on the concrete protecting this steel from corrosion. The wire netting in Monier pipe, after thirteen years' service, has been found in the same condition as when embedded. Professor Bauschinger has found an adhesive action between steel and cement mortar greater than the tensile strength of the latter.

During the construction of the Rapid Transit subway in New York City, a sidewalk laid in 1883 by Matt Taylor was torn up, and embedded in the concrete were found a number of steel rods which were in perfect condition after having been in the concrete for a period of nearly seventeen years.

Depositing Concrete.—Concrete should be deposited just as soon as mixed; it should be spread in layers about 8 inches thick and rammed solid, and each succeeding layer put on before the one below has set; in this way the concrete becomes one mass, and a solid block is the result.

The concrete should never be dumped from any height, but should be deposited with a shovel. If it is dumped any distance the stone aggregate will become separated from the mortar.

Where any concrete is to be put on top or against any that

is already set the surface of the concrete already in place should be coated over with a thick cement grout, as this will insure the two masses adhering together.

SPECIFICATIONS FOR CONCRETE, ETC.

As a guide for the superintendent the subjoined extracts from specifications, which are considered very good are given.

The following regarding concrete was taken from the specifications prepared by the Reclamation Service of the United States Geological Survey.

Concrete.—This includes all concrete in place, except pressure pipes.

The cement will be furnished by the Secretary of the Interior. The concrete to be used on all of the structures on this canal will be composed of Portland cement, sand, and gravel, or broken stone, in the proportion of one barrel of cement, in the packed condition in which it is sold, to seven full barrels of the same size, of the aggregates when mixed together. To facilitate the work experiments will be made by the contractor with the carriers, whether wheelbarrows, boxes, or cars, used by him, so that this proportion of cement to aggregates may be maintained as nearly as possible, and the engineer will supervise these experiments and fix said proportion for the kind of carrier used at each piece of work. He will also make experiments with the aggregates themselves so as to get the most compact mass that can be made from them, and for such experiments no extra allowance will be made to the contractor. If the cement comes in sacks, then 380 pounds net of cement will constitute a barrel, and any ordinary cement barrel open at one end containing not more than 3.7 cubic feet will be used for measuring the aggregates. If broken stone is used, it must be hard and compact, and satisfactory to the engineer. The entire product of the crusher will be taken, provided there is not more than ten (10) per cent of the volume composed of dust or screenings. All of the rock must be of such sizes as will pass through a screen with two (2) inch square mesh. If gravel is used it must be clean, hard, and heavy, having at least a specific gravity of 2, and screened into three different sizes. None of the gravel is to exceed 2 inches in diameter. The mixture of such sizes will be made in the proportion fixed by

the engineer. A promiscuous mixture of sand and gravel will not be accepted. The sand must be clean and sharp and free from any clayey matter.

The mixing of the concrete, if hand labor is used, will be done in the following manner: A tight floor of either planks or sheet iron will be used for the mixing in all cases. The sand must be dry, and will first be piled on the floor with the cement in the proper proportions; the mass will then be shovelled over as many times as are necessary to make a thorough mixture of sand and cement; sufficient water will then be added to make a stiff mortar and the mass shovelled over twice or more, as may be necessary. The stone or gravel, which should be well wet, will then be added, and the entire mass shovelled over twice or more before shovelling into the carriers. This mixing must be done to the satisfaction of the engineer. If the mixing is done by machine, the latter will be subject to approval by the engineer. If at any time the machine fails to perform the mixing in a manner satisfactory to the engineer, it must be made satisfactory or removed, and another machine substituted, or mixing by hand resorted to. . . .

In all concrete walls over 2 ft. thick hard boulders, or fragments of hard sound rock, not exceeding 1 ft., or less than 6 ins., in any dimension, may be placed by hand in the soft concrete, provided no such stone comes nearer than 2 ins. to the exterior surface of the wall, or to any other boulder or stone so placed. . . . All concrete shall be well tamped, if put in dry, with heavy tamping-bars, until moisture appears on the surface; and, if wet, with suitable bars and shovels, so that porosity and rough surface may be avoided. Concrete will be used "wet" wherever practicable, and "dry" only when the nature of the work renders its use unavoidable.

Mortar.—The following, regarding proportions of mortar, is taken from Cooper's "General Specifications for Foundations and Substructures":

"24. Cement mortar will be made by thoroughly incorporating the cement and sand in the following proportions, viz., one barrel of 300 pounds of natural cement and 12 cubic feet of sand, or one barrel of 375 pounds of Portland cement and 16 cubic feet of sand, with sufficient water to obtain the proper consistency.

"28. For foundations below the surface of the ground where the concrete will not be exposed to the action of running water

or to weather, the concrete shall be made of the following proportions: For each barrel of natural cement, 12 cubic feet of sand and 24 cubic feet of broken stone or coarse gravel.

"29. For monolithic piers and abutments, for cylindrical and wooden box piers, and for foundations where there is a liability to the action of running water or where the bottom is soft or of unequal firmness, the concrete shall be made of the following proportions: One barrel of Portland cement, 10 cubic feet of sand and 20 cubic feet of broken stone or coarse gravel."

MORTAR, GROUT, AND CONCRETE.—The following specifications were prepared for the concrete work of the retaining-walls of the Pennsylvania R. R. Terminal Station, New York City:

In proportioning materials for mortar, grout, and concrete, 1 volume of cement shall be taken to mean 380 lbs. net. One volume of sand or broken stone shall be taken to mean $3\frac{1}{2}$ cu. ft. packed or shaken down. Sand and broken stone shall be measured in barrels or rectangular boxes. Measurements in wheelbarrows will not be permitted.

In preparing mortar, the specified amounts of cement and sand shall first be mixed dry to a uniform color. The water shall be added in such a manner as not to wash out any of the cement and the mixing proceeded with until the mortar is thoroughly mixed and of uniform consistency. The proportions of cement and sand will generally be 1 to $2\frac{1}{2}$ by volume, but when the work is wet, the proportion of sand shall be reduced as required by the engineer.

Grout will generally be in the proportion of 1 part of cement to 1 part of sand by volume. The materials shall be thoroughly mixed dry, and water then added, while the mixing proceeds, until the grout is of the required consistency. The mixing shall be continued vigorously, preventing the separation of sand, until the entire amount mixed is used.

Concrete will be in the proportion of 1 volume of cement to 3 volumes of sand and 6 volumes of stone, except in special cases where the engineer may require different proportions. For copings and bridge seats to a depth of 9 ins. and in narrow confined places, the smaller sized stone shall be used, and the proportions of sand and stone may be reduced to 2 volumes of the former and 3 volumes of the latter to 1 volume of cement. Whenever practicable the concrete shall be machine-mixed;

the mixing-machine shall be a rotary mixer, and of a pattern that will mix the concrete in batches and permit the definite measurement of the materials for each batch. When the engineer considers it impracticable to mix by machine, it may be mixed by hand, in the same proportions as above specified. The mixing shall be done on a platform of boards or planks securely fastened together. The cement and sand shall first be mixed and made into mortar as described. The broken stone, previously wetted, shall then be added and the mortar and stone turned over with shovels until the mortar is uniformly distributed through the mass and every stone is coated with mortar.

Where the walls of concrete masonry exceed 6 ft. in thickness, masses of stone may be built in; such stone shall be clean, hard, compact, and free from cracks or other unsoundness. They shall be set in at least 6-in. beds of concrete and have full bearings therein. They shall be set on their largest beds and shall be at least 6 ins. apart at every point and at least 12 ins. from the face of the wall. No stone shall be more than 2 ft. in thickness. The large stones shall not in the aggregate exceed 25 per cent of the total volume of the masonry containing them.

The degree of moisture for mortar, grout, and concrete shall be at all times as required by the engineer or his inspector; in general mortar shall be plastic, grout shall be fluid enough to be pumped, and concrete shall be of such consistency that it will quake when being deposited, but not wet enough to cause the stone to separate from the mixture.

Concrete shall be deposited in the work in such a manner as not to cause separation of mortar and stone. It shall be laid quickly in layers not exceeding 9 ins. in thickness and thoroughly rammed with rammers of such form and material as the engineer may approve; special shaped rammers will be required for corners and other places where ordinary rammers would not be effective. Compact, dense concrete must be obtained with all the voids between the stones filled with mortar. If voids are discovered at any time, the defective concrete shall be removed and immediately replaced by concrete of such mixture and in such manner as the engineer may direct.

When the placing of the concrete is suspended, the engineer may require a joint to be formed in a manner satisfactory to

him, so that the fresh concrete, when added, may have a bond. Before depositing fresh concrete the entire surface on which it is to be laid shall be cleaned, washed, brushed, and slushed over with grout of cement without sand.

The surface of freshly laid concrete shall be protected from injury in such a manner and for such time as the engineer may require; concrete injured in any manner shall be removed.

Water used in mortar, grout, and concrete shall be clean fresh water.

No mortar, grout, or concrete which has commenced to set shall be used anywhere in the work. Retempering of mortar or grout which has commenced to set will not be permitted.

Forms for concrete shall be substantial and must preserve their accurate shape until the concrete has set. Where the concrete will show in the finished work, the face of the form shall be built of matched and dressed planking finished truly to the lines and surfaces shown on the plans. Adequate measures shall be taken to prevent the adhesion of mortar to the forms. Forms which have become warped or distorted shall be replaced immediately.

Faces which will show in the finished work shall be true to the form intended and shall be smooth and free from cavities due to shortage of mortar. Exposed faces shall have a facing of mortar, 2 ins. thick, deposited simultaneously with the corresponding layers of concrete and separated from the concrete by a metal diaphragm of approved form. After the mortar and concrete have been deposited the diaphragm shall be removed and the materials well worked together by spading and tamping, so as to insure their bonding. Plastering the face after removing the forms will not be permitted. The facing mortar shall contain 1 volume of cement to 2½ volumes of sand. Copings and bridge seats shall be finished with a layer of mortar 1 in. thick laid on the fresh concrete, thoroughly worked into its surface and finished smooth to true lines and surface by trowelling. They shall be kept damp and protected from the sun and rain for a period of at least 10 days.

Forms shall not be removed until permission has been given by the engineer.

Immediately after the forms are removed the exposed faces of the walls shall be washed over with a neat cement grout applied with a whitewash-brush.

Rock surfaces shall be thoroughly washed and cleaned before

concrete is deposited against them, and no concrete shall be deposited in water.

If leaks appear on the surface of the concrete at any time after removing the form, the contractor shall, at his own cost and expense, remove the concrete through which the water passes and replace it with sound concrete, and shall conduct the water to the base of the wall through channels or pipes in the concrete or take such other measures as the engineer may require.

Sidewalk Construction. — In sidewalk work the superintendent must see that the foundations are excavated to the required depth, and that the foundation is put in of the material specified (broken stone or cinders are usually used for this purpose). Whatever material is used it should be rammed solid, and it is well to have it wet as it is laid, as it will then pack more solid.

When the concrete base of the walk is put down the superintendent should see that it is not made too wet or the water will run down through the foundation, taking a large part of the cement with it. The base of concrete should be thoroughly rammed, and before it sets the top or finishing coat should be put on. so that the top coat will take firm hold of the base and they will set and dry as one layer. The base and top coat are usually put down in blocks or sections about 4 or 5 feet wide, according to the size blocks it is desired to divide the walk into. Each alternate section is put down and laid between two pieces of 2×4 studding as guides. In this way a man can work from both sides of the section. After the first series of alternate sections are laid and set hard enough, they can be covered with plank and the men can work off these to fill in the balance of the walk.

The blocks should be cut through with a trowel or a strip of paper laid in the joints so the blocks will not become cemented together, which is likely to cause the blocks to crack through the middle in case there is any settlement. Some contractors use a thin strip of steel in the joint, which is taken out after the cement sets, but a strip of paper can easily be cut at the top of the cement and there is no danger of breaking off corners as with the steel plate when it is pulled out of the joint.

In finishing the top coat, the superintendent should see that it is floated and trowelled smooth, and that all joints and outside edges of the blocks are run with the jointing-tool; he should

see that the top coat is mixed stiff enough so it will set up ready for trowelling as desired, and should not permit any dry cement to be sprinkled on to take up the surplus water. Dry cement used for this purpose will cause the finished top to have a mottled appearance, or cause small hair cracks; these cracks are also caused by too much trowelling, as this brings the cement to the top and makes the top too rich. The cement should be floated and not trowelled until it is stiff enough, so that with a little trowelling it can be brought to a smooth surface. The top coat should not be less than 1 inch thick, and should be mixed in proportions of 1 cement to 1 of sand or fine granite chips.

Sidewalks should never be laid in freezing weather, and if laid in hot weather must be well protected from the heat.

They should be kept covered for four or five days and wet several times a day during this period.

The base and top coat must be made of the same cement; Portland and natural cements will not adhere together and should never be used, one for the base and the other for the top coat.

The following specifications are used by the city of Seattle, Wash., for sidewalks, etc.

Concrete shall be mixed as follows: Upon a tight platform of evenly laid plank of sufficient size; a correct proportion of gravel shall be evenly spread, and in no case more than 8 ins. deep. All material for concrete shall be accurately measured in suitable sized boxes. No counting by shovels or other approximation will be allowed. To determine the proper proportions, a barrel of cement weighing not less than 400 lbs. gross shall be taken as measuring $3\frac{1}{2}$ cu. ft. In a separate box the correct proportion of sand and cement shall be mixed dry until the whole mass is one even color. The gravel shall then be wetted and the mixture of dry sand and cement shall be evenly spread over it. Commencing at the corners, the men shall, with shovels, turn the mass over away from the centre, and coming back, turn it to the centre. In addition to the thorough wetting of the stones, if, in the judgment of the city engineer, it will be necessary, sufficient water shall be added to the mass by a rosehead sprinkler to enable the material to become thoroughly incorporated, and the process of mixing shall be continued until the surface of each stone is well covered with mortar. The concrete shall be spread upon the foundation as soon as mixed in a layer of such depth that after

having been thoroughly compacted with iron-shod rammers, 7 ins. square and weighing not less than 40 lbs., it shall not be in any place less than 3½ ins. thick, and the upper surface shall be parallel with and not less than ½ in. below the proposed surface of the completed pavement. To insure this the concrete shall be struck with a gauge which shall be shod with a steel plate not less than ⅛ in. in thickness. Special care shall be taken to thoroughly tamp the concrete in all cases. It shall be tamped until a thin layer of water appears on the surface.

At such points as may be directed by the city engineer, and which shall be approximately 120 ft. apart, all concrete sidewalks shall have a joint ½ in. in width, extending entirely through the concrete base and wearing surface. As soon as the concrete is thoroughly set, this joint shall be carefully cleaned and immediately poured full, even with the surface, with hot grade "D" asphalt, or with pavers' pitch No. 6.

When the bottom course is completed, and before the concrete has begun to set, the finishing or wearing course shall be laid down. The correct proportions of sand and cement shall be thoroughly mixed dry until of one uniform color and sufficient water added to make a mortar of proper consistency. The mortar shall be colored by mixing lampblack therewith, at the rate of about 2 lbs. of lampblack to 1 bbl. of cement. This quantity may be varied to produce the shade desired. The lampblack shall be thoroughly mixed with the cement mortar in such manner as to produce a uniform and even shade satisfactory to the city engineer. Special care must be taken to thoroughly trowel down the mortar in order to secure a perfect bond with the concrete base. It shall then be carefully smoothed to a uniform surface, which must not be disturbed after the first setting takes place.

V-shaped grooves ¼ inch in depth shall then be made with a suitable tool, dividing the pavement into blocks 2 feet square. The thickness of the completed wearing surface must not be less than ½ in. at any point. On steep grades the cement coating shall be roughened in such manner as the city engineer may direct.

When the sidewalk is completed it shall be covered with such material as may be directed and kept moist by sprinkling for at least one week. The sprinkling shall be done as often as may be necessary to keep the sidewalk constantly moist.

The contractor will be required to stamp his name in letters 1 in. high and ¼ in. deep twice in each block on each side of street.

All concrete shall be laid in short sections and immediately covered with the wearing surface. Retempering of concrete or mortar will not be permitted. All mortar or concrete that has begun to set before ramming is completed shall be removed from the work. Any concrete or mortar that fails to show proper bond, or that fails to set after, in the opinion of the city engineer, it has been allowed sufficient time, shall be taken up and replaced by the contractor at his own expense with new concrete or mortar of proper quality.

Granolithic Sidewalk.—The following extract is taken from specifications prepared and used by the supervising architect of the U. S. Treasury Department:

The sidewalk shall be of 4 ins. of concrete with 1-in. finishing coat laid on 8 ins. of broken stone or cinders, the stone or cinders to be well rolled or tamped before the concrete is laid. The concrete shall be composed of one volume of Portland cement, two volumes of sand, and three volumes of clean hard stone broken to pass through a 1-in.-mesh sieve. Lay off in rectangular slabs about 4 ft. square, the joints to extend at least half way through the concrete, and before the concrete commences to set spread the finish coat, composed of equal volumes of Portland cement and finely crushed granite, mixed with only enough water to dampen the mass, as dusting with dry cement in finishing will not be permitted.

Trowel to smooth even surface cut through on lines coinciding with the joints in the concrete and finish the joints with a V-shaped tool. Leave 1½-in. margin around each slab.

In all work under the supervising architect samples of materials to be used must be submitted and approved before the work is commenced.

Weight of Concrete:

Cinder concrete..........	about	105	lbs.	per	cubic	foot
Crushed-stone concrete...	"	140	"	"	"	"
Gravel concrete..........	"	150	"	"	"	"
Slag concrete............	"	135	"	"	"	"

Per cent of strength of concrete at different ages:

30	days	old,	60	per	cent	of full	strength.
60	"	"	75	"	"	"	"
90	"	"	85	"	"	"	"
120	"	"	90	"	"	"	"
180	"	"	95	"	"	"	"
360	"	"	100	"	"	"	"

THE COMPOSITION OF CONCRETE FOR VARIOUS USES.

Nature of Work.	Proportions.				
	Cement	Sand.	Broken Stone.	Lime.	
Sidewalks, base	1	2	5	......	3-in. foundation of brokenstone, gravel, or cinders from 6 to 12 ins. deep.
Sidewalks, surface	1	1	....	......	1-in. crushed granite or sand.
Concrete, general use	1	3	7	......	Broken stone from ½ to 2 ins. in diameter.
Portland cement, lime, mortar	1	7	....	1	
Concrete bridge foundations and abutment walls	1	3	6	......	Stone to pass ring 1½ ins. in diameter.
Concrete haunches, arches, catch-basins	1	2	5	......	Stone to pass ring 1½ ins. in diameter.
Plastering faces of concrete arch and catch-basins	1	1½	....	......	
Stable floors, base	1	1½	3	......	3 ins. thick.
Stable floors, surface	1	1	....	......	2 ins. thick, hard-trowelled. Very fine sand, or preferably crushed granite.
Repairing masonry	1	3	....	......	
Stucco	1	3	....	¼	½ to ¾ in. thick.
Plastering brick wall, first coat containing hair	1	......	....	¼	½ in. thick.
Plastering brick wall, second coat applied before the first has set	1	2	....	......	¼ in. thick.
Concrete tanks, cisterns, etc.	1	2	5	......	Stone to pass 1-in. ring.
Concrete pillars, posts, walls, etc.	1	2	3	......	Broken stone to ¾-in. ring.
Ornamental work	1	2	3	......	Fine-crushed granite.
Cinder and cement concrete for fire-proof floors	1	2½	6 parts steam cinders	......	
Cement grout for pouring between concrete blocks	1	1	....	......	Water should be added in sufficient quantity to produce a fluid condition.

Concrete Wash.—The facing of concrete work employed by the Wabash Ry. for bridge abutments of concrete and concrete-steel consists in applying a facing wash composed of 1 part of plaster of Paris to 3 parts of cement, made very thin

SPECIFICATIONS FOR CEMENT-SIDEWALK CONSTRUCTION IN VARIOUS CITIES.

City.	Foundation.		Base.		Wearing Surface.		Dry Coating	Size of Blocks.	Guarantee, Years.
	Thickness, Inches.	Material.	Thickness, Inches.	Proportions.	Thickness, Inches.	Proportions. Cement. Sand.	Proportions. Cement. Sand.		
Boston.	12	Broken stone, gravel, or cinders.	3	1:2:5	1	1:1	....	Bet. 3½–6 ft. sq.	10
Rochester, N. Y.	6	Sand, gravel, broken stone, or cinders.	†	1:5	1	2:3	....	....	3
Philadelphia, Pa.	3	Sand, gravel, broken-brick stone, or cinders	3	....	2	1:2	1:1	....	......
Washington, D. C.	0	....	4	1:2:5	1	2:3	1:1	....	5
Chicago, Ill.	0 or 12*	Cinders.	4¼ av.	1:2:5	¾	1:1	....	5 ft. × 6 ft.	10
Milwaukee, Wis.	4	Cinders or broken stone.	2½	1:3:5	1	1:1	....	Bet. 24–36 sq. ft.	......
St. Louis, Mo.	8	Cinders.	3½	1:3	½	1:1	....	....	1
Omaha, Neb.	4	Gravel, slag, or stone.	3	1:2:4	1	1:2	3:1	....	5

* Twelve-inch cinders required where the soil is not clean sand. † Specified for each contract.

and put on with whitewash-brushes. This has been found very satisfactory.

LIME CONCRETE.—In Paris a concrete is much used, composed as follows:

Sand and gravel 8 parts, burned and powdered earth 1 part, pulverized clinkers and cinders 1 part, and unslaked hydraulic lime $1\frac{1}{2}$ parts. These materials are thoroughly mixed while dry and then dampened. This mixture sets in a short while and becomes very hard and strong in a few days. It is claimed for this concrete that it is not liable to crack or scale.

Experiments for volume on cement, sand, gravel, broken stone, mortar, and concrete are shown in the following table, the volumes being measured loose:

Cement.	Volume of Loose Cement.	Water Added by Measure.	Volume of Stiff Cement Paste.
Portland cement (Atlas)	1.00	0.35	0.78
Natural cement. Louisville	1.00	0.43	0.78

Remarks.—6.56 barrels of cement = 1 cubic yard measured loose.

Aggregates.	Volume Loose.	Solids.	Voids.
1. Sand, moist, fine, will pass 18-mesh sieve	1.00	0.57	0.43
2. Sand, moist, coarse, will not pass 18-mesh sieve	1.00	0.65	0.35
3. Sand, moist, coarse and fine mixed (ordinary)	1.00	0.62	0.38
4. Sand, dry, coarse and fine mixed	1.00	0.70	0.30
5. Stone screenings and stone dust	1.00	0.58	0.42
6. Gravel, $\frac{3}{4}$ in. and under, 6 per cent coarse sand	1.00	0.67	0.33
7. Broken stone, 1 in. and under	1.00	0.54	0.46
8. Broken stone, $2\frac{1}{2}$ ins. and under, dust only screened out	1.00	0.59	0.41
9. Broken stone, $2\frac{1}{2}$ ins. and under, most small stones screened out	1.00	0.55	0.45

MORTARS WITH NO. 3 SAND.

Parts of sand mixed with 1 part of cement	1.0	1.5	2.0	2.5	3.0	3.5	4.0	5.0
Volume of slush mortar	1.40	1.78	2.17	2.55	2.98	3.39	3.82	4.65
Required for 1 cubic yard:								
Cement, bbls	4.70	3.70	3.04	2.58	2.21	1.94	1.72	1.41
Sand, cubic yards	0.71	0.84	0.92	0.98	1.01	1.03	1.05	1.08
Volume of dry facing mortar (rammed)	1.22	1.57	1.93	2.28	2.64	2.99	3.35	4.08
Required for 1 cubic yard:								
Cement, bbls	5.40	4.18	3.41	2.88	2.49	2.20	1.96	1.61
Sand, cubic yards	0.82	0.95	1.04	1.10	1.14	1.17	1.20	1.23

MATERIALS REQUIRED TO MAKE DIFFERENT CLASSES OF CONCRETE FOR CONNECTICUT AVE. BRIDGE, WASHINGTON, D. C.

The following concrete preparations were determined by Mr. A. W. Dow, Inspector of Asphalts and Cements, and W. J. Douglas, Engineer of Bridges, D. C.

Class A.

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.
9.00 cu. ft. sand.
20.25 " " stone.
Yielded 21.4 cu. ft. concrete when rammed into place.

Class B.

1:2½:6 (broken stone).

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.
11.25 cu. ft. sand.
27.00 " " stone.
Yielded 27.66 cu. ft. concrete when rammed into place.

Class B.

1:2½:3:3 (3 gravel and 3 stone).

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.
11.25 cu. ft. sand.
13.50 " " gravel.
13.50 " " stone.
Yielded 27.66 cu. ft. concrete when rammed into place.

Class C.

1:3:10 (gravel).

4 bags = 1 bbl. Vulcanite cement = 378.25 lbs. = 4.5 cu. ft.
13.5 cu. ft. sand.
45.0 " " gravel.
Yielded 45 cu. ft. of concrete when rammed into place.

NOTES ON CEMENT CONCRETE, ETC.—Good cement should be a uniform bluish-gray color throughout; yellow checks or places indicate an excess of clay or that the cement has not been sufficiently burned; and it is then probably a quick-setting cement of low specific gravity and deficient strength.

CONCRETES.

Mixtures.			Material Required for One Cubic Yard Rammed Concrete. Stone, 1 Inch and Under, Dust Screened Out.			Stone, 2½ Ins. and Under, Dust Screened Out.			Stone, 2½ Ins., with Most Small Stone Screened Out.			Gravel, ¾ Inch and Under.		
Cement.	Sand.	Stone.	Cement, Bbls.	Sand, Cu. Yds.	Stone, Cu. Yds.	Cement, Bbls.	Sand, Cu. Yds.	Stone, Cu. Yds.	Cement, Bbls.	Sand, Cu. Yds.	Stone, Cu. Yds.	Cement, Bbls.	Sand, Cu. Yds.	Gravel, Cu. Yds.
1	1.0	2.0	2.57	0.39	0.78	2.63	0.40	0.80	2.72	0.41	0.83	2.30	0.35	0.74
1	1.0	2.5	2.29	0.35	0.70	2.34	0.36	0.89	2.41	0.37	0.92	2.10	0.32	0.80
1	1.0	3.0	2.06	0.31	0.94	2.10	0.32	0.96	2.16	0.33	0.98	1.89	0.29	0.86
1	1.0	3.5	1.84	0.28	0.98	1.88	0.29	1.00	1.88	0.29	1.05	1.71	0.26	0.91
1	1.5	2.5	2.05	0.47	0.78	2.09	0.48	0.80	2.16	0.49	0.82	1.83	0.42	0.73
1	1.5	3.0	1.85	0.42	0.84	1.90	0.43	0.87	1.96	0.45	0.89	1.71	0.39	0.78
1	1.5	3.5	1.72	0.39	0.91	1.74	0.40	0.93	1.79	0.41	0.96	1.57	0.36	0.83
1	1.5	4.0	1.57	0.36	0.96	1.61	0.37	0.98	1.64	0.38	1.00	1.46	0.33	0.88
1	1.5	4.5	1.43	0.33	0.98	1.46	0.33	1.00	1.51	0.35	0.16	1.34	0.31	0.91
1	2.0	3.0	1.70	0.52	0.77	1.73	0.53	0.79	1.78	0.54	0.81	1.54	0.47	0.73
1	2.0	3.5	1.57	0.48	0.83	1.61	0.49	0.85	1.66	0.50	0.88	1.44	0.44	0.77
1	2.0	4.0	1.46	0.44	0.89	1.48	0.45	0.90	1.53	0.47	0.93	1.34	0.41	0.81
1	2.0	4.5	1.36	0.42	0.93	1.38	0.42	0.95	1.43	0.43	0.98	1.26	0.38	0.86
1	2.0	5.0	1.27	0.39	0.97	1.29	0.39	0.98	1.33	0.39	1.03	1.17	0.36	0.89
1	2.5	3.5	1.45	0.55	0.77	1.48	0.56	0.79	1.51	0.58	0.81	1.32	0.50	0.70
1	2.5	4.0	1.35	0.52	0.82	1.38	0.53	0.84	1.42	0.54	0.87	1.24	0.47	0.75
1	2.5	4.5	1.27	0.48	0.87	1.29	0.49	0.88	1.33	0.51	0.91	1.16	0.44	0.80
1	2.5	5.0	1.19	0.46	0.91	1.21	0.46	0.92	1.26	0.48	0.96	1.10	0.42	0.83
1	2.5	5.5	1.13	0.43	0.94	1.15	0.44	0.96	1.18	0.44	0.99	1.03	0.39	0.86
1	2.5	6.0	1.07	0.41	0.97	1.07	0.41	0.98	1.10	0.41	1.03	0.98	0.37	0.89
1	3.0	4.0	1.26	0.58	0.77	1.28	0.58	0.78	1.32	0.60	0.80	1.15	0.52	0.72
1	3.0	4.5	1.18	0.54	0.81	1.20	0.55	0.82	1.24	0.57	0.85	1.09	0.50	0.75
1	3.0	5.0	1.11	0.51	0.85	1.14	0.52	0.87	1.17	0.54	0.89	1.03	0.47	0.78
1	3.0	5.5	1.06	0.48	0.89	1.07	0.49	0.90	1.11	0.51	0.93	0.97	0.44	0.81
1	3.0	6.0	1.01	0.46	0.92	1.02	0.47	0.93	1.06	0.48	0.97	0.92	0.42	0.84
1	3.0	6.5	0.96	0.44	0.95	0.98	0.44	0.96	1.00	0.45	1.01	0.88	0.40	0.87
1	3.0	7.0	0.91	0.42	0.97	0.92	0.42	0.98	0.94	0.42	1.05	0.84	0.38	0.89
1	3.5	5.0	1.05	0.56	0.80	1.07	0.57	0.82	1.11	0.59	0.85	0.96	0.50	0.76
1	3.5	5.5	1.00	0.53	0.84	1.02	0.54	0.85	1.06	0.56	0.89	0.92	0.48	0.78
1	3.5	6.0	0.95	0.50	0.87	0.97	0.51	0.89	1.00	0.53	0.92	0.88	0.46	0.80
1	3.5	6.5	0.92	0.49	0.91	0.93	0.49	0.92	0.96	0.51	0.95	0.83	0.44	0.82
1	3.5	7.0	0.87	0.47	0.93	0.89	0.47	0.95	0.91	0.49	0.98	0.80	0.43	0.85
1	3.5	7.5	0.84	0.45	0.96	0.86	0.45	0.98	0.86	0.47	1.01	0.76	0.41	0.87
1	3.5	8.0	0.80	0.42	0.97	0.82	0.43	1.01	0.81	0.45	1.04	0.73	0.39	0.89
1	4.0	6.0	0.90	0.55	0.82	0.92	0.56	0.84	0.95	0.58	0.87	0.83	0.51	0.77
1	4.0	6.5	0.87	0.53	0.85	0.88	0.53	0.87	0.91	0.55	0.90	0.80	0.49	0.79
1	4.0	7.0	0.83	0.51	0.89	0.84	0.51	0.90	0.87	0.53	0.93	0.77	0.47	0.81
1	4.0	7.5	0.80	0.49	0.91	0.81	0.50	0.93	0.84	0.51	0.96	0.73	0.44	0.83
1	4.0	8.0	0.77	0.47	0.93	0.78	0.48	0.95	0.81	0.49	0.98	0.71	0.43	0.86
1	4.0	8.5	0.74	0.45	0.95	0.76	0.46	0.98	0.78	0.47	1.01	0.68	0.42	0.88
1	4.0	9.0	0.71	0.43	0.97	0.73	0.44	1.01	0.75	0.45	1.04	0.65	0.40	0.89
1	5.0	9.0	0.66	0.50	0.90	0.67	0.52	0.93	0.70	0.53	0.96	0.61	0.46	0.83
1	5.0	10.0	0.62	0.47	0.95	0.63	0.48	0.96	0.65	0.50	1.00	0.57	0.43	0.87

Cement that will stand a high test for seven days may have an excess of lime, which will cause it to deteriorate. The twenty-eight-day test is, therefore, very useful.

The most dangerous feature in Portland cement is the presence of too much magnesia and an excess of free lime, the latter indicated by the cracks and distortions in the test cakes and the former in the deficiency of tensile strength of the briquettes. Over 3 per cent of magnesia is excessive and dangerous.

For general information the following building material will make 1 cubic yard of concrete: 2400 pounds crushed stone, 295 pounds cement, 880 pounds sand, 700 pounds rough building stone.

Cement work which is to be painted must be fully hardened and dry. The best results are obtained after the concrete is a year old. A good preparatory coating for oil paint is a solution of water-glass in 4 parts of water. After two applications the surface is washed with water and water-glass applied again. When thoroughly dry the paint can be used.

The quality of cement-work is always improved by keeping it wet, especially during the process of setting. Cement should in no case be disturbed after it has attained its initial set.

When metal moulds are used for forming concrete, or metal lining for wooden forms, ordinary pork fat has been successfully used to prevent adhesion.

The white efflorescence sometimes seen defacing concrete is not permanent or serious, and it is easily removed by scrubbing with broom and water. It is caused by the wetting and drying of the concrete, which leaches out the alkali in the masonry from sand, water, and cement.

Sieves used to ascertain the fineness of cement:

No. 50.............	2,500	meshes to the square inch
No. 74.............	5,476	" " " " "
No. 100...........	10,000	" " " " "
No. 200...........	40,000	" " " " "

In moulding a concrete block the operation should always be continuous and great care exercised in compacting the cement next to all parts of mould which mould the exterior surfaces. Great care should be exercised in removing the moulds, which under ordinary circumstances can be done twenty-four hours after the concrete has been in place. The block, after removal

of the mould, should be shaded by canvas or heavy burlap and kept thoroughly wetted for a number of days.

Neat cement reaches a greater strength at short periods than sand mixtures. Long-time tests prove, however, that sand mixtures ultimately attain equal and often greater strength than neat cement.

The compressive strength of cement is from eight to twelve times the tensile strength.

White sand or marble dust used in making concrete gives the finished work a lighter color than is attained by using ordinary sand.

When salt is used in concrete, to prevent freezing, it should always be thoroughly dissolved in water before it is added to the cement—one pound of salt to every 18 gallons of water when the thermometer is at 32° F., and one additional ounce of salt for every further degree below 32.

CONCRETE CONSTRUCTION.—Concrete was the most important of all the building materials used by the Romans, and the developments of the past few years have brought about changes until it is now recognized as one of the most important materials used at the present time.

A test as to the durability of concrete is found in the Pantheon at Rome, which was built by Agrippa, 27 B.C., nearly 2000 years ago. The circular walls are about 20 feet in thickness, and the roof is a hemispherical cement concrete dome with a 30-foot opening in the top and spanning in the clear 142 feet 6 inches. This is the most remarkable instance in the world's history, showing the great strength and durability in cement-concrete construction.

Concrete construction is usually done by building wood forms or moulds and ramming them full of concrete, either solid or with hollow walls. The superintendent must see that these forms are built tight and strong enough to withstand the pressure of the concrete while being rammed. If the concrete is to be reinforced with steel of any kind he must see that it is put in at the proper place and in sufficient quantity.

Forms.—Pine is the best wood for building forms or moulds; some other woods (especially California redwood) will stain the finished surface of the concrete.

Mouldings, rustications, etc., are built in the form and the concrete is rammed into them.

It is advisable to wet the concrete several times a day for

several days after it has been put in place, to prevent it drying too fast. In building forms for foundations, walls, etc., care must be taken to provide chases and openings for all pipes, etc., and where any wood is to be fastened to the concrete to build in bolts with the nut end sticking out from the face of the wall a sufficient distance to bolt up the woodwork.

Concrete is one of the best and most reliable of building materials when mixed and put in place in a proper manner; where there have been failures in concrete construction it has generally been due to one of the following causes: Bad centring and forms, bad material, poor mixing, insufficient ramming, or insufficient and poor reinforcement.

It will be the duty of the superintendent to see that all the requirements of the plans and specifications are carried out to their strict intentions and meaning.

Concrete building-blocks in imitation of stone, etc., are now being made, which require close inspection to tell that they are not the natural stone. These are made in any shape or form desired and given any desired finish. In use these blocks are set and pointed the same as stone ashlar.

Concrete-steel Construction.—The following regulations for reinforced concrete-steel construction were issued by the Bureau of Buildings of the Borough of Manhattan, Greater New York, September 9, 1903:

1. The term "concrete-steel" in these regulations shall be understood to mean an approved concrete mixture reinforced by steel of any shape, so combined that the steel will take up the tensional stresses and assist in the resistance to shear.

2. Concrete-steel construction will be approved only for buildings which are not required to be fireproof by the Building Code, unless satisfactory fire and water tests shall have been made under the supervision of this bureau. Such tests shall be made in accordance with the regulations fixed by this bureau and conducted as nearly as practicable in the same manner as prescribed for fire-proof floor fillings in Section 106 of the Building Code. Each company offering a system of concrete-steel construction for fire-proof buildings must submit such construction to a fire and water test.

3. Before permission to erect any concrete-steel structure is issued complete drawings and specifications must be filed with the superintendent of buildings, showing all details of the construction, the size and position of all reinforcing-rods, stirrups, etc., and giving the composition of the concrete.

4. The execution of work shall be confided to workmen who shall be under the control of a competent foreman or superintendent.

5. The concrete must be mixed in the proportions of one of cement, two of sand, and four of stone or gravel; or the proportions may be such that the resistance of the concrete to crushing shall not be less than 2000 pounds per square inch after hardening for 28 days. The tests to determine this value must be made under the direction of the superintendent of buildings. The concrete used in concrete-steel construction must be what is usually known as a "wet" mixture.

6. Only high-grade Portland cements shall be permitted in concrete-steel construction. Such cements, when tested neat, shall, after one day in air, develop a tensile strength of at least 300 pounds per square inch; and after one day in air and six days in water shall develop a tensile strength of at least 500 pounds per square inch; and after one day in air and 27 days in water shall develop a tensile strength of at least 600 pounds per square inch. Other tests, as to fineness, constancy of volume, etc., made in accordance with the standard method prescribed by the American Society of Civil Engineers' Committee, may from time to time be prescribed by the superintendent of buildings.

7. The sand to be used must be clean, sharp, grit sand free from loam or dirt, and shall not be finer than the standard sample of the Bureau of Buildings.

8. The stone used in the concrete shall be a clean, broken trap-rock or gravel of a size that will pass through a $\frac{3}{4}$-inch ring. In case it is desired to use any other material or other kind of stone than that specified, samples of same must first be submitted to and approved by the superintendent of buildings.

9. The steel shall meet the requirements of Section 21 of the Building Code.

10. Concrete-steel shall be so designed that the stresses in the concrete and the steel shall not exceed the following limits:

	Pounds per Square Inch.
Extreme fibre stress on concrete in compression	500
Shearing stress in concrete	50
Concrete in direct compression	350
Tensile stress in steel	16,000
Shearing stress in steel	10,000

11. The adhesion of concrete to steel shall be assumed to be not greater than the shearing strength of the concrete.

12. The ratio of the moduli of elasticity of concrete and steel shall be taken as 1 to 12.

13. The following assumption shall guide in the determination of the bending moments due to the external forces: Beams and girders shall be considered as simply supported at the ends, no allowance being made for the continuous construction over supports. Floor plates, when constructed continuous and when provided with reinforcement at top of plate over the supports, may be treated as continuous beams, the bending moment for uniformly distributed loads being taken at not less than $\frac{WL}{10}$; the bending moment may be taken as $\frac{WL}{20}$ in the case of square floor plates which are reinforced in both directions and supported on all sides. The floor plate to the extent of not more than ten times the width of any beam or girder may be taken as part of that beam or girder in computing its moment of resistance.

14. The moment of resistance of any concrete-steel construction under transverse loads shall be determined by formulas based on the following assumptions:

a. The bond between the concrete and steel is sufficient to make the two materials act together as a homogeneous solid.

b. The strain in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

c. The modulus of elasticity of the concrete remains constant within the limits of the working stresses fixed in these regulations.

From these assumptions it follows that the stress in any fibre is directly proportionate to the distance of that fibre from the neutral axis.

The tensile strength of the concrete shall not be considered.

15. When the shearing stresses developed in any part of a construction exceed the safe working-strength concrete, as fixed in these regulations, a sufficient amount of steel shall be introduced in such a position that the deficiency in the resistance to shear is overcome.

16. When the safe limit of adhesion between the concrete and steel is exceeded, some provision must be made for transmitting the strength of the steel to the concrete.

17. Concrete-steel may be used for columns in which the ratio of length to least side or diameter does not exceed 12.

The reinforcing-rods must be tied together at intervals of not more than the least side or diameter of the column.

18. The contractor must be prepared to make load tests on any portion of a concrete-steel construction, within a reasonable time after erection, as often as may be required by the superintendent of buildings. The tests must show that the construction will sustain a load of three times that for which it is designed without any sign of failure.

Approved September 9, 1903.

HENRY S. THOMPSON,

Superintendent of Buildings for the Borough of Manhattan.

CONCRETE-FLOOR CONSTRUCTION.—There are a number of different systems of concrete-floor construction and fireproofing, each being controlled by a different company, and it will be the duty of the superintendent to keep himself posted regarding all the different systems, so that when one is put under his supervision he can readily judge if it is being done right.

A system of floor construction may be perfectly reliable when properly constructed but with poor material or workmanship it may result in a weak floor.

Cinder concrete reinforced in different ways with steel is the usual construction, and the superintendent must see that all the materials are the best and the reinforcing and workmanship done in a proper manner.

The proportions for a good cinder concrete are one part cement, two parts sand, and five parts cinders.

Regarding fire-proof floors the New York Building Code says:

Sec. 106. *Fire-proof Floors.*—Fire-proof floors shall be constructed with wrought-iron or steel floor-beams so arranged as to spacing and length of beams that the load to be supported by them, together with the weights of the materials used in the construction of the said floors, shall not cause a greater deflection of the said beams than one-thirtieth of an inch per foot of span under the total load; and they shall be tied together at intervals of not more than eight times the depth of the beam. Between the wrought-iron or steel floor-beams shall be placed brick arches springing from the lower flange of the steel beams. Said brick arches shall be designed with a rise to safely carry the imposed load, but never less than one and one-quarter inches for each foot of span between the beams, and they shall have a thickness of not less than four inches for spans of five feet or less and eight inches for

spans over five feet, or such thickness as may be required by the Board of Buildings. Said brick arches shall be composed of good, hard brick or hollow brick of ordinary dimensions laid to a line on the centres, properly and solidly bonded, each longitudinal line of brick breaking joints with the adjoining lines in the same ring and with the ring under it when more than a four-inch arch is used. The brick shall be well wet and the joints filled in solid with cement mortar. The arches shall be well grouted and properly keyed. Or the space between the beams may be filled in with hollow-tile arches of hard-burnt clay or porous terra-cotta of uniform density and hardness of burn. The skew-backs shall be of such form and section as to properly receive the thrust of said arch; and the said arches shall be of a depth and sectional area to carry the load to be imposed thereon, without straining the material beyond its safe working load, but said depth shall not be less than one and three-quarter inches for each foot of span. not including any portion of the depth of the tile projecting below the under side of the beams, a variable distance being allowed of not over six inches in the span between the beams, if the soffits of the tile are straight; but if said arches are segmental, having a rise of not less than one and one-quarter inches for each foot of span, the depth of the tile shall be not less than six inches. The joints shall be solidly filled with cement mortar as required for common brick arches and the arch so constructed that the key block shall always fall in the central portion. The shells and webs of all end construction blocks shall abut, one against another. Or the space between the beams may be filled with arches of Portland-cement concrete, segmental in form, and which shall have a rise of not less than one and one-quarter inches for each foot of span between the beams. The concrete shall be not less than four inches in thickness at the crown of the arch and shall be mixed in the proportions required by Section 18 of this Code. These arches shall in all cases be reinforced and protected on the under side with corrugated or sheet steel, steel ribs, or metal in other forms weighing not less than one pound per square foot and having no openings larger than three inches square. Or between the said beams may be placed solid or hollow burnt-clay, stone, brick, or concrete slabs in flat or curved shapes, concrete or other fire-proof composition, and any of said materials may be used in combination with wire cloth, expanded metal wire

strands, or wrought-iron or steel bars; but in any such construction and as a precedent condition to the same being used, tests shall be made as herein provided by the manufacturer thereof under the direction and to the satisfaction of the Board of Buildings, and evidence of the same shall be kept on file in the Department of Buildings, showing the nature of the test and the result of the test. Such tests shall be made by constructing within inclosure walls a platform consisting of four rolled steel beams, ten inches deep, weighing each twenty-five pounds per lineal foot, and placed four feet between the centres, and connected by transverse tie-rods, and with a clear span of fourteen feet for the two interior beams and with the two outer beams supported on the side walls throughout their length, and with both a filling between the said beams and a fire-proof protection of the exposed parts of the beams of the system to be tested, constructed as in actual practice, with the quality of material ordinarily used in that system and the ceiling plastered below, as in a finished job; such filling between the two interior beams being loaded with a distributed load of one hundred and fifty pounds per square foot of its area and all carried by such filling; and subjecting the platform so constructed to the continuous heat of a wood fire below, averaging not less than seventeen hundred degrees Fahrenheit for not less than four hours, during which time the platform shall have remained in such condition that no flame will have passed through the platform or any part of the same, and that no part of the load shall have fallen through, and that the beams shall have been protected from the heat to the extent that after applying to the under side of the platform at the end of the heat test a stream of water directed against the bottom of the platform and discharged through a one and one-eighth inch nozzle under sixty pounds pressure for five minutes, and after flooding the top of the platform with water under low pressure, and then again applying the stream of water through the nozzle under the sixty pounds pressure to the bottom of the platform for five minutes, and after a total load of six hundred pounds per square foot uniformly distributed over the middle bay shall have been applied and removed, after the platform shall have cooled, the maximum deflection of the interior beams shall not exceed two and one-half inches. The Board of Buildings may from time to time prescribe additional or different tests than the foregoing for systems of filling between

iron or steel floor-beams, and the protection of the exposed parts of the beams. Any system failing to meet the requirements of the test of heat, water, and weight as herein prescribed shall be prohibited from use in any building hereafter erected. Duly authenticated records of the tests heretofore made of any system of fire-proof floor filling and protection of the exposed parts of the beams may be presented to the Board of Buildings, and if the same be satisfactory to said Board, it shall be accepted as conclusive. No filling of any kind which may be injured by frost shall be placed between said floor-beams during freezing weather, and if the same is so placed during any winter month, it shall be temporarily covered with suitable material for protection from being frozen. On top of any arch, lintel, or other device which does not extend to and form a horizontal line with the top of the said floor-beams, cinder concrete or other suitable fire-proof material shall be placed to solidly fill up the space to a level with the top of the said floor-beams, and shall be carried to the under side of the wood floor-boards in case such be used. Temporary centring when used in placing fire-proof systems between floor-beams shall not be removed within twenty-four hours or until such time as the mortar or material has set. All fire-proof floor systems shall be of sufficient strength to safely carry the load to be imposed thereon without straining the material in any case beyond its safe working load. The bottom flanges of all wrought-iron or rolled-steel floor and flat roof beams, and all exposed portions of such beams below the abutments of the floor-arches, shall be entirely encased with hard-burnt clay, porous terra-cotta, or other fire-proof material allowed to be used for the filling between the beams under the provisions of this section, such incasing material to be properly secured to the beams.

The exposed sides and bottom plates or flanges of wrought-iron or rolled-steel girders supporting iron or steel floor-beams, or supporting floor-arches or floors, shall be entirely incased in the same manner. Openings through fire-proof floors for pipes, conduits, and similar purposes shall be shown on the plans. After the floors are constructed no opening greater than eight inches square shall be cut through said floors unless properly boxed or framed around with iron. And such openings shall be filled in with fire-proof material after the pipes or conduits are in place.

Sec. 107. *Incasing Interior Columns.*—All cast-iron, wrought-iron, or rolled-steel columns, including the lugs and brackets on

same, used in the interior of any fire-proof building, or used to support any fire-proof floor, shall be protected with not less than two inches of fire-proof material, securely applied. The extreme outer edge of lugs, brackets, and similar supporting metal may project to within seven-eighths of an inch of the surface of the fireproofing.

Expanded-metal Floor Construction.—The following cuts show the method of concrete floor construction used by the various expanded-metal companies. This is a flat cinder concrete arch reinforced with expanded metal as shown.

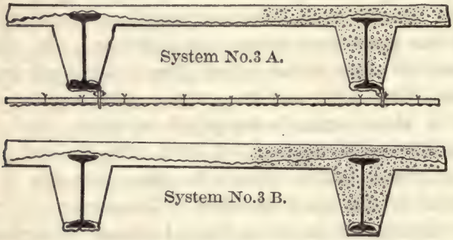


FIG. 125.

Systems 3 A and 3 B, Fig. 125, are alike except that 3 A has a flat ceiling supported on the under flange of the floor-beams. This system fireproofs the beam by a haunch fill of the cinder concrete.

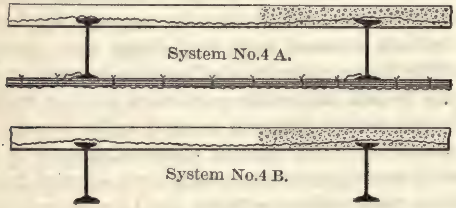


FIG. 126.

Systems 4 A and 4 B, Fig. 126, are alike except that 4 A has a flat ceiling suspended. By changing the thickness of the concrete and the quantity of metal spans, from four to ten feet can be built on this system.

System 5, Fig. 127, differs from 4 B in that the floor-beam is protected with a coat of plaster on a metal lath, which is furred to the beams, giving the panelled ceiling. The usual way of putting

on this furring is to nail it up to the concrete as shown, but a better way is to put it in place before the floor is laid and turn it up over the top of the beam and wire it fast.

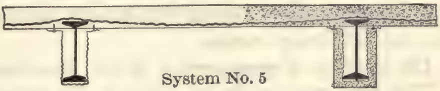


FIG. 127.

System 7, Fig. 129, is developed from System 8, where the beams are too deep for a fill above the concrete construction.

FIG. 128.

System 8, Fig. 128, is designed to be used where the floor-beams are light and can be used with economy with beams not over 7 ins. deep or more than 4 ft. 6 ins. on centres.

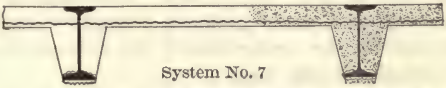


FIG. 129.

Systems 9 A and 9 B, Fig. 130, are designed for heavy loads, and is one of the strongest systems used.

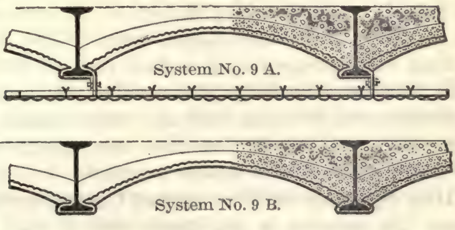


FIG. 130.

In any of the above systems it will be the duty of the superintendent to see that the centring is put up solid enough to withstand the tamping of the concrete. See that the concrete

is mixed and put in place correctly, and as the strain on the expanded metal is a tensile one, see that it is stretched tight before the concrete is put on top.

A floor-arch of this construction, as shown by Fig. 131, was tested at the Government Hospital for Insane, at Washington, D. C., with the following results.

In Fig. 131 is given a cross-section of the floor-slab as built for test. The test was made on 15-inch beams which had

Fig. 131.—Cross-section of Floor-slab Tested at Washington, D. C.

bearings on foundations 20 feet apart, and a floor was built covering the whole distance from bearing to bearing. The test load was applied on an area 5′ 6″ × 5′ 6″, making a trifle over 30 square feet of area. Standard practice in this connection was followed, which means that the concrete plate was 3 inches thick, and the formula of mixture was 1 part cement, 2 parts sand, and 6 parts of bituminous-coal cinders. The illustration in this connection of the cross-section clearly shows the details of the case.

The arch was thirty-eight days old when it was first loaded with 600 pounds per square foot. Under that weight the arch showed a deflection of $\frac{1}{16}$ inch. There was also a slight deflection to the beams themselves. On the following day the load was increased to 1256 pounds per square foot, and at that time the deflection amounted to $\frac{3}{16}$ inch in the concrete plate, with an increased deflection of the beams. The succeeding day the load was increased until a final load of 1800 pounds per square foot was carried. This resulted in very marked beam deflection and twisting, and also some cracks appeared in the concrete plate, but the load was carried without falling for some days, when it was finally removed.

Roebling System of Fire-proof Construction.—In this system the concrete is reinforced with $\frac{1}{8}'' \times 2''$ flat steel bars set on edge, and by a quarter turn is hooked over the beam at each end. These bars act as flitch-plates when bedded in the concrete, and when put in place in a proper manner give great strength to the concrete.

The superintendent should see that the twist on the bar is made so it comes tight against the beam. The author has seen these bars put in where the twist was 4 or 5 inches away from the beam, and in this space the bar would be on its flat, as shown by Fig. 132, and have very little strength. He should

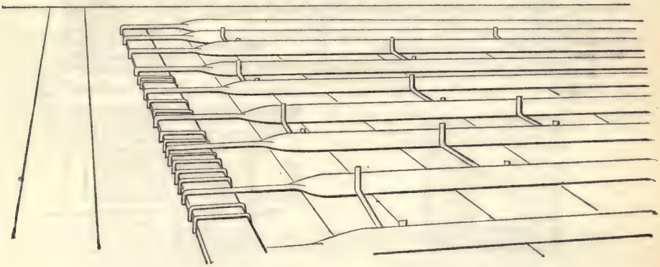


Fig. 132.

also see that the bars are hooked tight over the beam, as the strength depends materially on this.

An improvement on this system is made by running the bars across the beam and bolting them together, as shown by Fig. 133.

This gives more strength, as there is no twist, and the entire bar is on edge. This system is sometimes put in by hanging

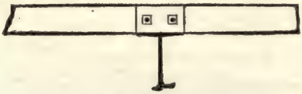


Fig. 133.

wire lath to the bars and depositing the concrete directly on the lath, but concrete deposited in this way must be made very dry or the water will run out, taking a large part of the cement with it, and if made dry, there is no way of ramming it to make it solid; by using a wood centre a much better and stronger floor can be made.

The following cuts show various types of this floor construction.

The "System A," or arch construction, with flat ceiling, is illustrated by Fig. 134. It consists of a wire-cloth arch, stiffened

by *woven-in* steel rods, which is sprung between the floor-beams, and abuts into the seat formed by the web and lower flange

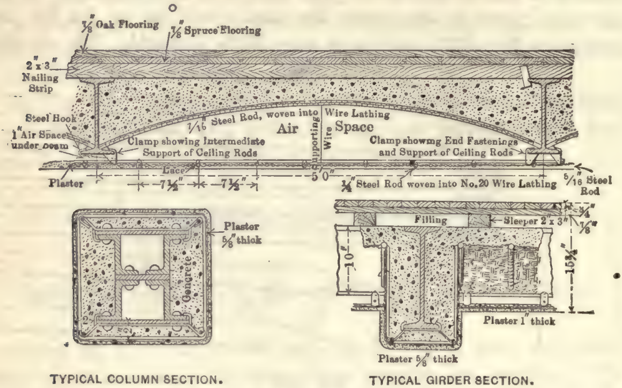


FIG. 134.—Adapted for Public Buildings, Offices, Theatres, Hotels, Schools, Churches, Banks, Libraries, Hospitals, Residences, etc.

of the I beams. On this wire centring Portland-cement concrete is deposited and allowed to harden.

The ceiling consists of a system of supporting rods attached to the lower flanges of the floor-beams by a patent clamp which offsets the rods below the I beams. Under these rods, and securely laced to them, is the Roebling Standard wire lathing, with the *woven-in* ¼-inch solid-steel stiffening-ribs crossing the supporting rods at right angles.

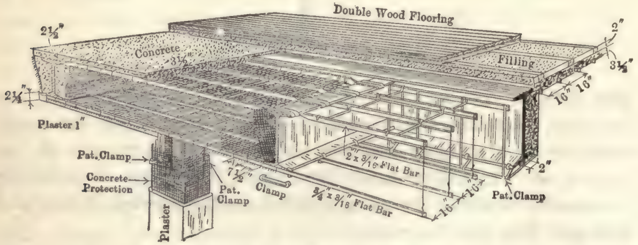


FIG. 135.—System B—Flat Construction.

The "System B," or flat construction, is illustrated by Figs. 135 and 136. It consists of a light iron framework imbedded

in concrete and spans the interval between the iron beams in the form of a slab. The light iron framework consists of flat iron or steel bars set on edge and spaced 16 inches, centre to centre, with a quarter turn at both ends where the bars rest upon the iron beams. Spacers of half oval iron are placed at suitable intervals to separate and brace the bars. The Roebling Standard wire lathing, with the ¼-inch solid-steel stiffening-rib *woven in* every 7½ inches, is applied to the under side of the bars, the stiffening-ribs running crosswise under the bars and laced to them at every intersection. On the wire lathing so supported, cinder concrete is deposited, thoroughly imbedding the light ironwork.

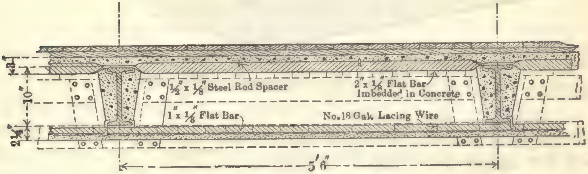


Fig. 136.—System B—Type 1.
(Dotted lines indicate temporary wood centring.)

The Renton System of Fire-proof Floors.—The Renton system of floor construction as shown by the following cuts is a flat concrete arch of cinder concrete, reinforced with ordinary barb wire. The strain on the wire being tensile, the superintendent should see that it is stretched tight and made fast at each end. This method of construction 4½ inches thick has been tested to carry a load of 650 pounds per square foot.

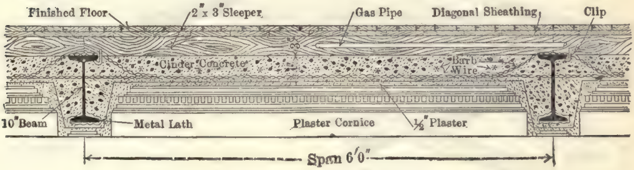


Fig. 137.—System No. 1.

System No. 1.—This is perhaps the most popular system, as it gives a minimum thickness of floor and is adapted to

the conditions most commonly found in fire-proof buildings. It can be used for spans up to 8 feet, although a span of 6 feet is the most desirable.

Weight of concrete, about 34 pounds per square foot.

Weight of entire floor as shown, 52 pounds per square foot.

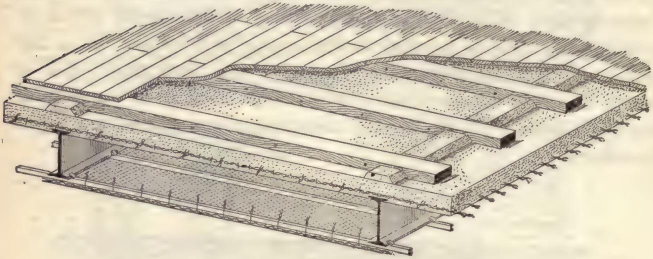


FIG. 138.—System No. 2.

SYSTEM No. 2.—This system, as shown by Fig. 138, can be used for spans between floor-beams of from 6 to 10 feet, and has ample strength for most mercantile buildings, factories, etc. It can be used either with or without the suspended flat ceiling shown.

Weight of entire floor, without ceiling, 40 pounds per square foot.

Weight of suspended ceiling, including plaster, 10 pounds per square foot.

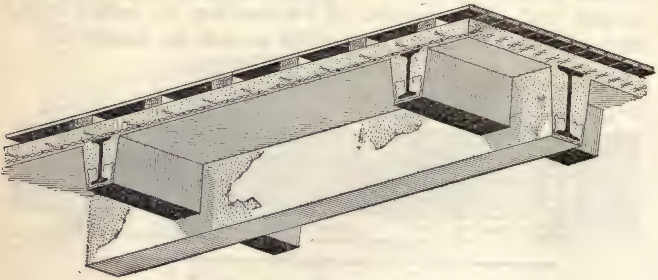


FIG. 139.—System No. 3.

SYSTEM No. 3.—This system, Fig. 139, is the same as No. 2, except that the floor-beams are thoroughly protected and the flat ceiling is omitted.

Weight per square foot for 4 inches of concrete, 10-inch steel beams, 6 feet on centres, 2×3 sleepers and a single wood floor, no plastering, 48 pounds.

Weight with cement top, 59 pounds per square foot. For ½-inch plastering add 5 pounds per square foot.

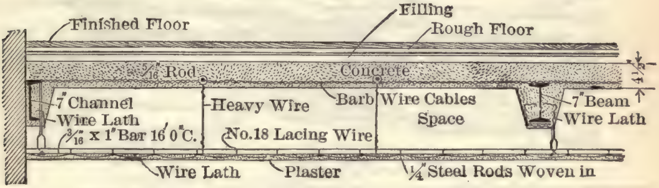


Fig. 140.—System No. 4.

System No. 4.—This system, Fig. 40, is adapted to public buildings and all buildings in which considerable strength, absolute fire protection, and a flat ceiling are required.

Weight complete as shown, 60 pounds per square foot.

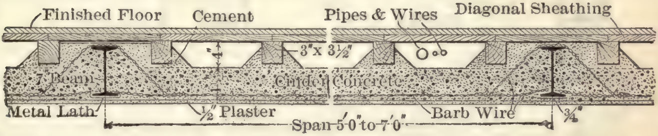


Fig. 141.—System No. 5.

System No. 5.—This system, Fig. 141, is especially adapted to apartment houses, private residences, etc.

System No. 6 (Arch Construction).—This system, Fig. 142,

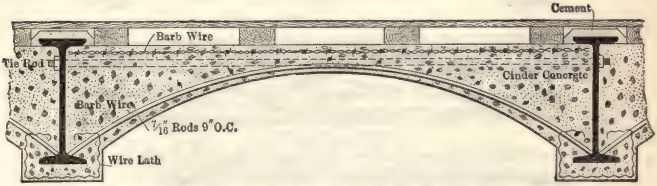


Fig. 142.—System No. 6 (Arch Construction).

is designed for warehouses, storage buildings, etc., and all buildings in which great strength and absolute fire protection are required. With a span of 6 feet this floor is guaranteed

to sustain a distributed load of 1000 pounds per square foot over its entire surface without falling.

"Kuhne's Sheet-metal Structural Element."—The following cuts show a system of floor construction in which a

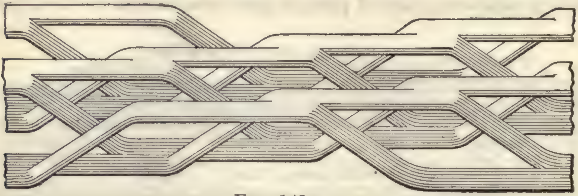


Fig. 143.

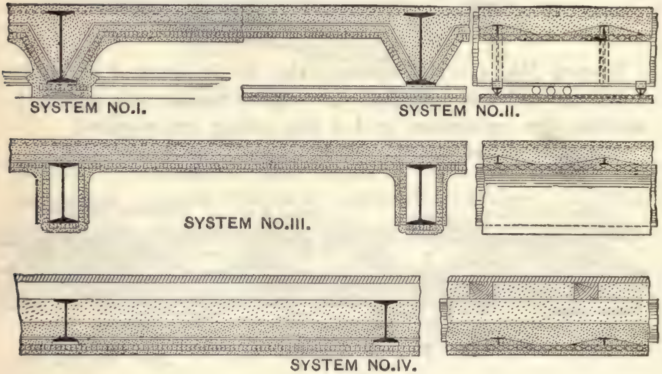


Fig. 144.

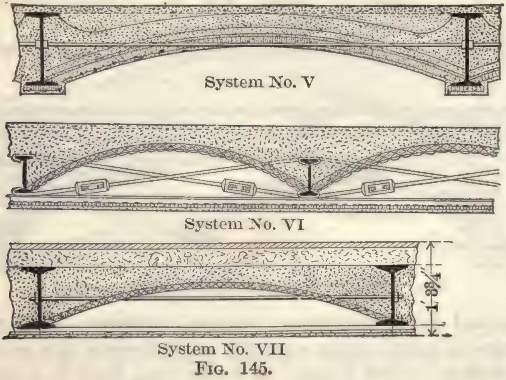


Fig. 145.

patent metal lath which is cut and bent so as to form a series of trusses is used as a reinforcing material. This lath is manufactured by the Truss Metal Lath Company, New York.

Fig. 143 shows a view of the lath, and Figs. 144 and 145 show methods of floor construction.

International System.—This system, used by the International Fence and Fireproofing Company, Columbus, Ohio, is shown by the following cuts, 146 and 147. In this system the concrete is reinforced with wire rods and wire cables.

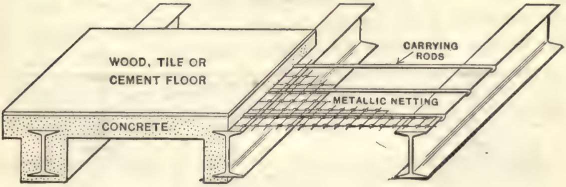


FIG. 146.

The strain on the wire and cables being a tensile one the superintendent must see that they are well fastened at each end.

When rods are used as shown in Fig. 147 and hooked over

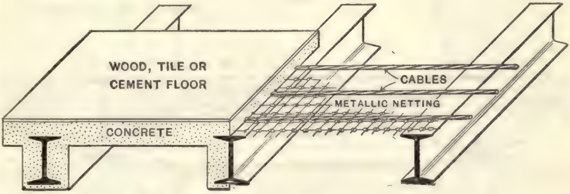


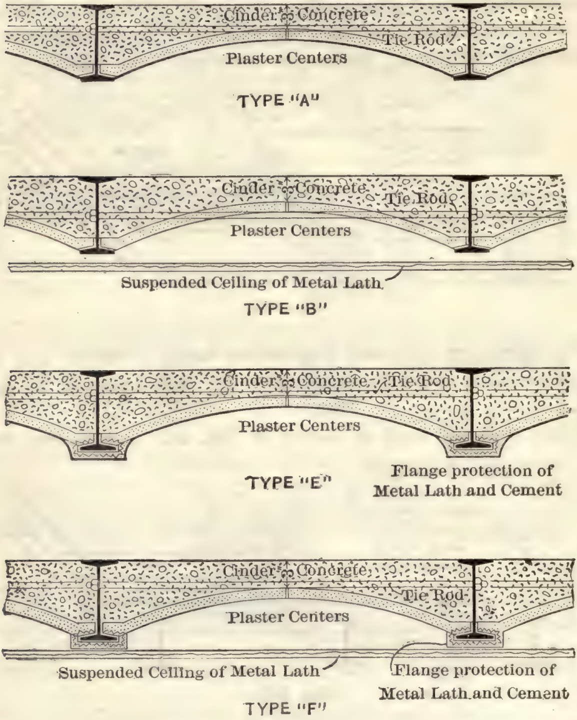
FIG. 147.

the beam, the rod should be bent while hot, so that when the hook is made over the beam the rod will be drawn tight and have no play.

Fig. 146 illustrates a flat arch, using the cabling system. I beams fully incased and reinforced with concrete, the cables running across the I beams and anchored thereto. The sheeting is distributed over the cables and both are imbedded well toward the bottom of the concrete stone. Anchors should be built in the wall to fasten the cables and sheeting when the walls are

built, and always have the brick laid in cement where ancho
are placed.

Fig. 147 represents flat arch with distributing rods, meta
lic sheeting, encased I beams, and section of concrete floo
Anchors should be built in the wall at a level with the top



TYPES OF VULCANITE FIRE-PROOF
FLOOR ARCHES

Fig. 148.

the I beams, upon which the ends and outside sheets are fastene
Inside laps are attached by means of loops on the edge whi
are interwrapped with a twist.

The Vulcanite Fire-proof Floor.—The Vulcanite fire-proof floor system, constructed by The Vulcanite Paving Company, Philadelphia, is a cinder concrete arch put in on a plaster-of-Paris centre, as shown by Fig. 148. The plaster-of-Paris centre is cast in sections and put in place on the lower flange of the beam and the concrete spread over it. This is a very strong system of floor construction, as the strain on the concrete is a compressive one.

Ferroinclave.—Ferroinclave is the name of a steel and cement fire-proof construction consisting of a sheet of steel corrugated into dovetail shape, and which is laid and fastened to the beams and the mortar or concrete spread on top.

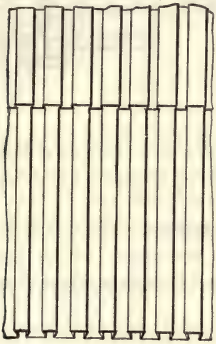


FIG. 149.

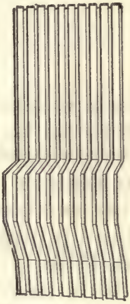


FIG. 150.—Sheet bent to shape.

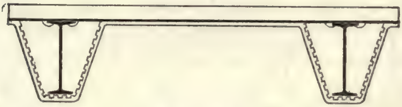


FIG. 151.

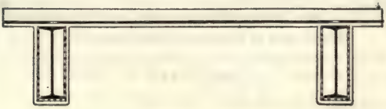


FIG. 152.

Figs. 149 and 150 show a sheet of the metal, and Figs. 151 and 152 show floor sections.

Buckeye Floor Construction.—Fig. 153 shows a method of floor construction patented and used by The Youngstown Iron and Steel Roofing Co., Youngstown, Ohio.

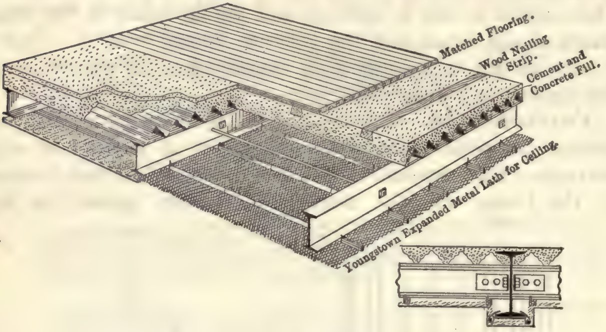


FIG. 153.

A series of corrugated metal troughs are furnished the exact length to lay on the beams, and these troughs are filled with the concrete to the desired depth.

Kahn System of Reinforcement.—Figs. 154 and 155 show a bar and method of using the same which has been patented and is used by The Trussed Concrete Steel Company, of Detroit, Mich.

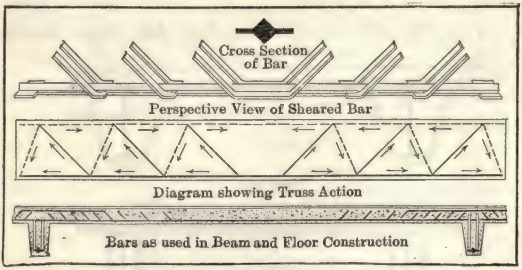


FIG. 154.

Metropolitan System.—This system, as shown by Figs. 156, 157, and 158, is a slab or arch made of plaster of Paris and wood chips, reinforced with wire cables in the form of

hog-chains and bedded in the concrete. The cables must be made secure at the ends and have just sag enough so that at

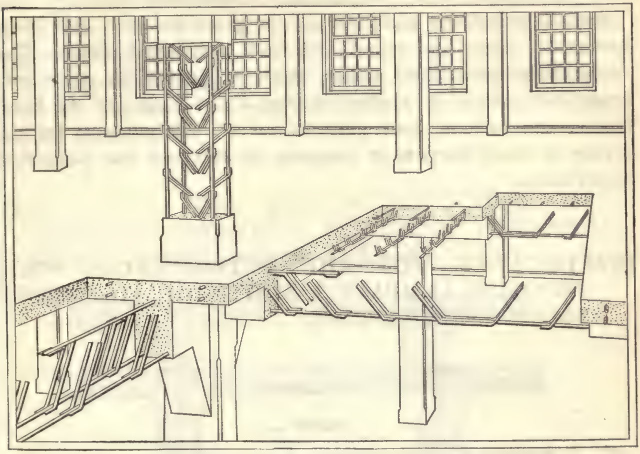


Fig. 155.

the low point they will be about one-half inch from the bottom of the concrete.

SPECIFICATIONS FOR ABOVE TYPE OF FLOOR.

By means of forms or centres placed about the bottom flanges of the floor beams and girders, a $1\frac{1}{2}''$ covering of composition, composed principally of plaster of Paris and wood chips, shall

Fig. 156.

be cast in place, protecting the bottom flanges of the floor beams and girders.

Cables, each composed of two No. 12 galvanized wires, twisted, shall be carried over the tops of the floor-beams and shall be secured to walls by anchors and bars; or where they end on a beam, shall be secured to it by strong hooks. These cables shall be laid parallel and pass under round iron bars midway

between the beams, so as to cause the cables to deflect uniformly. The cables shall be laid at distances apart from each other, varying from 1″ to 3″, according to the spans.

Forms or centres shall be put in place between the floor-beams 1″ below the round iron bars mentioned above. The composition mentioned above shall be poured in place and brought to a level ½″ above the tops of the flanges of the floor-beams and form a floor plate about 4″ thick, ready for the laying of wood sleepers or concrete on top and the plastering underneath.

SPECIFICATION FOR THE METROPOLITAN FIRE-PROOFING COMPANY'S SYSTEM OF FIRE-PROOF FLOOR CONSTRUCTION.

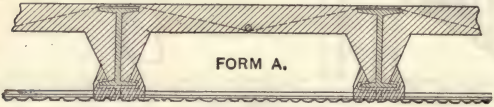


FIG. 157.

Metal clips shall be fastened to the bottom flanges of the floor-beams, which shall support 1″×3/16″ flat iron bars spaced about 16″ on centres running transversely with the floor-beams, the tops of such flats to be on a level about 1″ below the bottom flanges.

Blocks 1½″ thick of our composition, composed principally of plaster of Paris and wood chips, shall be fastened securely to the bottom flanges and against the webs of the floor-beams, covering the exposed portions.

To take the plaster there shall be fastened to the 1″ flats herring-bone pressed-steel lathing, coated with asphaltum.

Cables, each composed of two No. 12 galvanized wires, twisted, shall be carried over the tops of the floor-beams and shall be secured to walls by anchors or bars, or where they end on a beam shall be secured to it by strong hooks. These cables shall be laid parallel and pass under round iron bars midway between the beams so as to cause the cables to deflect uniformly. The cables shall be laid at distances apart from each other varying from 1″ to 3″, according to spans. Forms or centres shall be put in place between the floor-beams 1″ below the

round iron bars mentioned above. The composition mentioned above shall be poured in place and brought to a level about $\frac{1}{2}''$ above the tops of the flanges of the floor-beams and form a floor plate about 4″ thick ready for the laying of wood sleepers or concrete.

The exposed portions of the girders shall be covered with blocks of the same composition $1\frac{1}{2}''$ in thickness, securely fastened in place.

SPECIFICATION FOR THE METROPOLITAN FIRE-PROOFING COMPANY'S SYSTEM OF FIRE-PROOF FLOOR CONSTRUCTION, FORM A2.

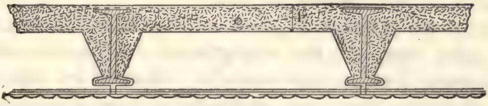


FIG. 158.

Metal clips shall be fastened to the bottom flanges of the floor-beams, which shall support $1'' \times \frac{3}{16}''$ flat iron bars spaced about 12″ on centres, running transversely with the floor-beams, the tops of such flats to be on a level about 1′ below the bottom flanges.

To take the plaster there shall be fastened to the 1″ flats herring-bone pressed-steel lathing, coated with asphaltum.

Cables, each composed of two No. 12 galvanized wires, twisted, shall be carried over the tops of the floor-beams and shall be secured to walls by anchors or bars, or where they end on a beam shall be secured to it by strong hooks. These cables shall be laid parallel and pass under round iron bars midway between the beams so as to cause the cables to deflect uniformly. The cables shall be laid at distances apart from each other varying from 1″ to 3″, according to spans. Forms or centres shall be put in place between the floor-beams 1″ below the round iron bars mentioned above. A composition composed principally of plaster of Paris and wood chips shall be poured in place and brought to a level about $\frac{1}{2}''$ above the tops of the flanges of the floor-beams covering the webs of the beams and forming a floor-plate about 4″ thick, ready for the laying of wood sleepers or concrete.

The exposed portions of the girders shall be covered with

blocks of the same composition, 1½″ in thickness, securely fastened in place.

The Ransome System.—The Ransome system of concrete and cold-twisted steel construction was invented by Mr. Ernest L. Ransome. The basis of this system is the combination of steel and concrete in such a manner as to give to the concrete all the tensional strength of steel, and thereby fully utilize the immense compressive strength inherent in the concrete. The patent for this system covers the use of cold-twisted rectangular steel bars, by means of which the spiral ribs formed upon the metal make a continuous lock between it and the concrete. By this means the ductility of the steel is controlled, defective steel detected, and a large percentage of strength added thereto.

The tensional strength of steel or iron (about 30 tons to the square inch) increases the strength of the concrete 100-fold. The Ransome bar strengthens the concrete so that in the heaviest floors for warehouse sand factories bars of only 1½ inches have been used. The extensive application of the Ransome system for fire-proof floors, spanning without steel beams, from 20 to 25 and 45 feet, represents one of its important successes.

To make a practical success of this principle a continuous bond between the iron and the concrete had to be invented, the ductility of the iron had to be controlled, and appliances for moulding had to be perfected, as well as means of controlling the shrinkage. Furthermore, it was desirable to give an artistic appearance to the structure. These, with other important and practical inventions, constituted the Ransome system.

This system of concrete-iron construction is universal in its application, covering the entire field now occupied by stone, brick, and terra-cotta, and is unrivalled for stairs, foundations, walls, floors, columns, partitions, harbor works, dry docks, piers, bridges, reservoirs, filter-beds, fortifications, retaining-walls, sidewalks, vault lights, etc.

The Ransome patents are owned by the Ransome Concrete Company, 26 Broadway, New York.

Hennebique System of Cement Concrete Construction.—The Hennebique system, Fig. 159, is not only a system of fire-proofing, but a mode of construction successfully applied to many uses, such as floors, bridges, reservoirs, docks, foundations, etc. Broadly speaking, the system, as

patented in 1898, is for concrete reinforced with ordinary round bars of iron or steel and stirrups of hoop iron.

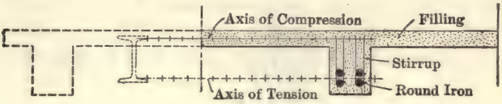


FIG. 159.—Section of Hennebique Floor.

The principle of the Hennebique system is to make the cement concrete subject only to compression stresses, resistance to which is its chief characteristic; and the iron subject to tensile stresses, which it is essentially adapted to meet. For floor construction plain, round iron bars, set in the lower part of a beam of rectangular or trapezoidal section, are the parts in tension; in that position the metal exerts its best quality, resistance in tension. A series of straps distributed along the beam connect the bar with the upper part of the concrete and make a series of fastenings which steady and support

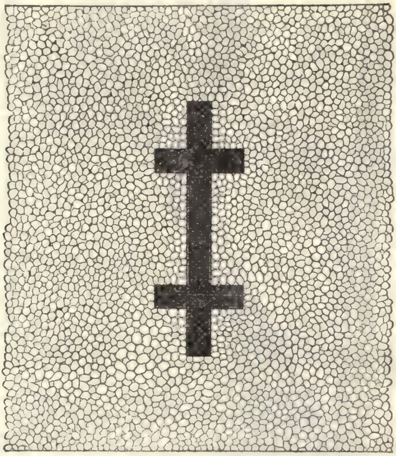


FIG. 160.—Two-inch Ribbed Bar Imbedded in 3½ Inches of Concrete.

the bar. They carry to the upper part of the concrete the stresses which in them are tensile, but which are then distributed as compression stresses through the body of concrete.

The Hennebique system has been applied to many important uses in bridge engineering and general building operations.

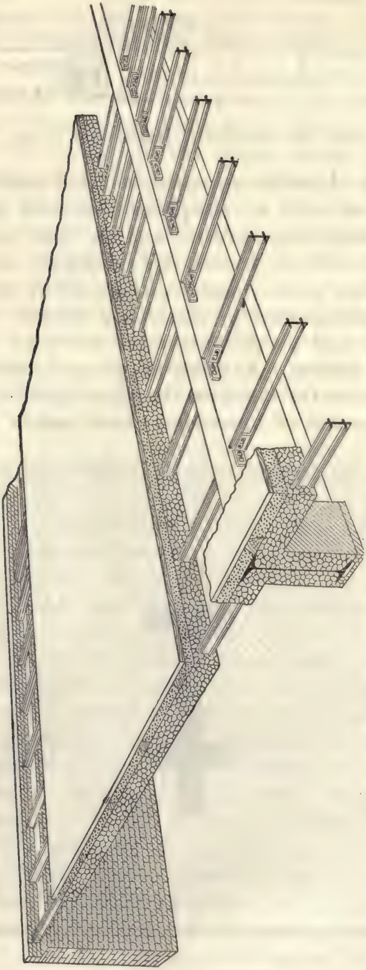


FIG. 161.—View of No. 1 Floor with Heavy Ribbed Bars Framed to Girders.

Columbian System of Floor Construction.—In the Columbian system, as shown by Figs 160, 161, and 162,

the concrete is reinforced with specially designed bars of steel hung on stirrups over the beams. This construction is guaranteed by the company to carry 200 pounds per square foot with a 3-inch arch, 6-foot span, 600 pounds per square foot with a 4-inch arch, 6-foot span, and 150 pounds per square foot on a $2\frac{1}{2}$-inch arch, 5-foot span, with a factor of safety of four.

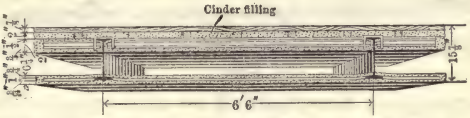
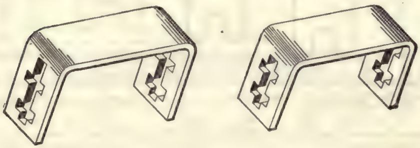
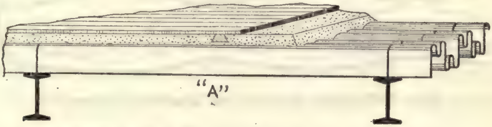


Fig. 162.—No. 3, Double Construction.



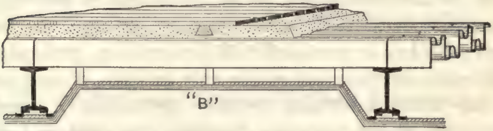
View of Stirrups for Bars, Floors Nos. 2 and 3.

Multiplex Steel-plate Floor Construction.—This construction, which is used by The Berger Manufacturing Company, of Canton, Ohio, is shown by Figs. 163–166. The



The Multiplex Steel Plate used in its simplest form

Fig. 163.



The Multiplex Steel Plate Floor with a Paneled Ceiling

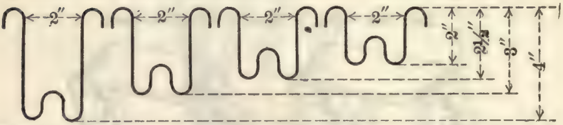
Fig. 164.

steel plate is corrugated and bent as shown, laid on top of the floor-beams and then filled with the cinder concrete

to a height of about 2 inches above the plate. The different methods of construction are shown in the cuts.

The Multiplex Steel Plate Floor with a Flat Ceiling.

FIG. 165.



Dimensions of the Multiplex Steel Plate as ordinarily used for Floor Arches.

FIG. 166.

The Thacher System of Concrete-steel Construction.—The concrete-steel arch, patented Jan. 10, 1899, and known as the Thacher system, may be described as follows: Steel bars (Fig. 167) in pairs, spaced at proper distances apart,

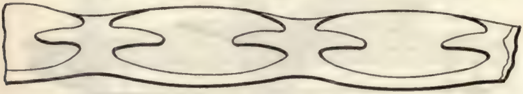


FIG. 167.—Bar used in the Thacher System.

and spliced at convenient intervals, are imbedded in the concrete near the outer and inner surfaces of the arch, and extend well into the abutments and piers. The bars of each pair have no connection with each other, except through the concrete, although each bar is provided with projections, preferably rivet-heads of extra height; but which may be lugs, dowels, or bolts, spaced at short intervals, thereby providing a mechanical reinforcement of the adhesion between the steel and the concrete, so that a complete crushing or shearing of the concrete must take place before a separation can be effected. The bars act as the flanges of a beam to assist the concrete in resisting the thrusts and bending moments to which the arch is sub-

jected. The shearing stresses are small, and are taken mostly by the concrete. The principal advantages claimed for this system are as follows: That it gives a larger moment of inertia, and consequently greater strength, for the same amount of steel; that a more reliable connection is secured between the steel and the concrete than in a system that depends on adhesion alone; and that the bars can be shipped straight in any convenient length and bent cold to any desired curve, resulting in less cost for manufacture and greater convenience in handling and shipping.

Cummings System of Reinforced Concrete Construction.—Fig. 168 shows a system of reinforced concrete

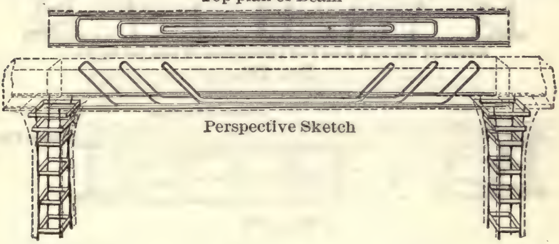


FIG. 168.

construction designed by Robert A. Cummings, Pittsburgh, Pa. The rod reinforcement as shown is bedded in the concrete beam.

Fig. 169 shows a corrugated steel bar used for concrete con-

⅞ in □ Bar. Net section, 0.55 □ in. Weight, 2.05 lbs. per ft.

FIG. 169.

struction by the St. Louis Expanded Metal Fireproofing Company.

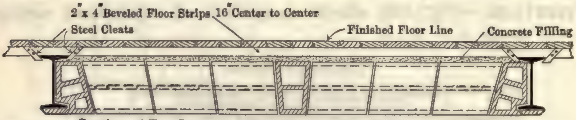
These bars are made of various sizes and strengths.

Where there will be a tensile strain on concrete in floor construction, it should be made of fine crushed stone so as to make the highest quality of tension concrete. Cinders should be used in construction only where the greatest strain is in compression.

TOP FILLING.—Before any concrete filling is put in on top of any floors, the concrete floors or arches should be swept clean and then thoroughly wet, so the filling will take hold to the concrete arch already in place.

This filling is generally not made as strong with cement as the concrete in the arches, the usual proportions being about 1 cement, 3 sand, and 6 cinder or other aggregate.

Terra-cotta Floor Construction.—Figs. 170 and 171 show the ordinary terra-cotta arch, Fig. 171 is what is known as side construction, and Fig. 170 end construction.



Section of Ten Inch Arch End Construction 34 Lbs. per Sq. Ft.

FIG. 170.

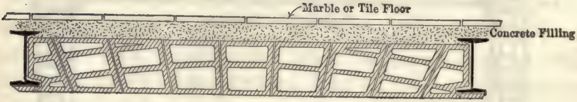


FIG. 171.

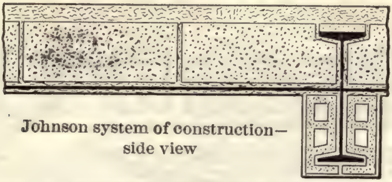
The main points to be observed in either of these arches are to see that the blocks are of the right size and that they are bedded in mortar the full width of the joint. The keys should be of a size so that they will shove into place and have a good bed of mortar.

The National Fire-proofing Co.'s Johnson System.—This system is a terra-cotta arch reinforced with wire, as shown by Fig. 172. The basis of this flooring is formed of large steel wires transversely interwoven with still larger wires placed 4 inches apart. These last run straight from bearing to bearing.

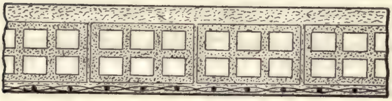
Over and through these wires is spread a bed of cement mortar and on this bed the tiles are set. On top of the tiles is spread 3 inches of cinder concrete. This makes a very strong floor.

"New York" Reinforced Terra-cotta Arch (Bevier Patent).—A system of reinforced terra-cotta arch construction now used by the The National Fireproofing Company is shown by Figs. 173–175.

In this construction a wire reinforcement in the form of a wire truss, the upper and lower chords being composed of



Johnson system of construction—
side view



Johnson system of construction—
end view

Johnson system—
25 feet between girders

FIG. 172.

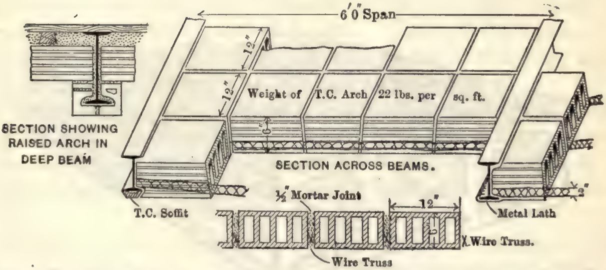


FIG. 173.—Above Arch Accepted by New York Building Department for Live Load of One Hundred and Fifty Pounds per Square Foot.

two No. 13 galvanized twisted wires and the diagonal members being single No. 14 wires, is bedded in the cross joints of the terra-cotta, thus adding strength to it.

The truss is placed on edge and runs from beam to beam in the vertical joint between adjoining blocks. the joint being about ½ inch wide and the mortar well grouted around the wires.

"Herculean" Flat Arch.—The floor construction shown by Fig. 176 is known as the "Herculean" arch, and is used by Henry Maurer & Son of New York.

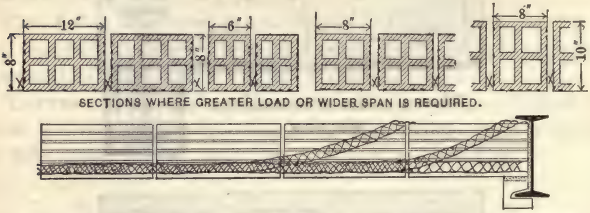


Fig. 174.—Half Section through Wide Span Arch, showing use of more than one piece of wire truss to give greater strength in centre and prevent shearing of blocks at ends of arch. Depth of blocks, number of trusses, and size of wires are proportioned to load and span.

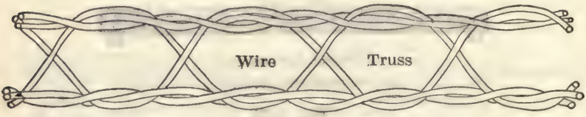


Fig. 175.—"New York" Reinforced Terra-cotta Arch (Bevier Patent).

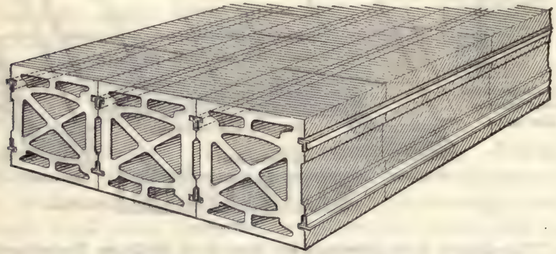


Fig. 176.—"Herculean" Flat Arch (Patented May 3, 1898, and February 6, 1900).

In this arch the terra-cotta is reinforced with steel tee irons as shown, and makes a very strong floor. In constructing this arch care should be taken to see that sufficient mortar is used so that when the tile blocks are shoved into position the mortar will fill all the spaces and the joint around the tee irons.

Fig. 177 shows a new style of terra-cotta arch of the end-construction system. As will be seen the number of webs in the blocks makes them very strong.

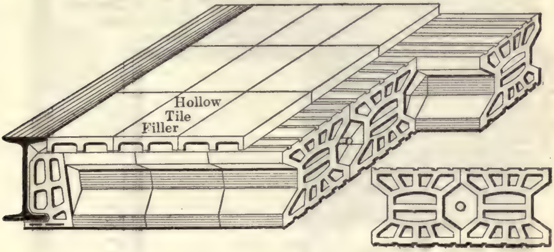


FIG. 177.

Fire-proof Partitions.—Each fireproofing company usually has its own system for putting up partitions, as well as floor construction, and the superintendent should keep himself familiar with all the different methods.

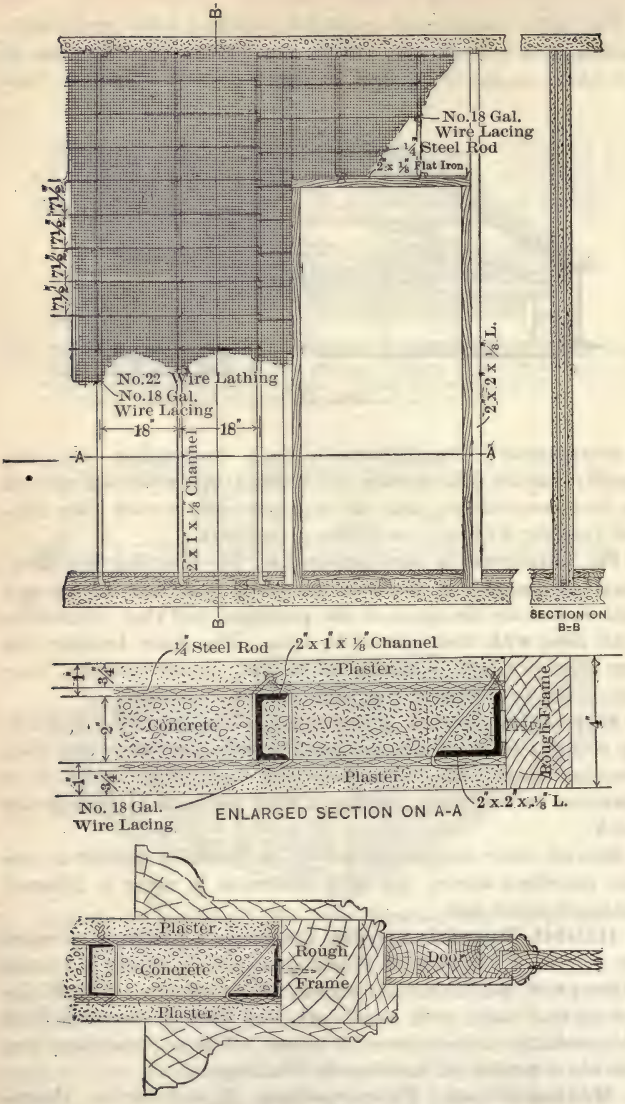
Fig. 178 shows the partition used by The Roebling Company. Small steel angles or channels are set up and fastened top and bottom to form the studs of the partition, and then covered on both sides with their wire-cloth lath. The space between the two sheets of lath is usually filled with cinder concrete, after which the two sides of the partition are plastered.

Expanded-metal Partition.—This partition is made by setting up small channel bars to form the studs and then covering them with expanded-metal lath, after which it is plastered on both sides, making a solid partition 1½ or 2 inches thick.

Several other companies put up a partition similar to the one described above; the only difference is using a different make of metal lath.

Rabbit Partition.—Fig. 179 shows a partition patented by Samuel E. Rabbit of Washington, D. C., which is termed a fire-proof partition. As shown, strips of wood $\frac{7}{8}'' \times 2''$ are set up and lathed with wood lath, and then plastered on both sides solid to a thickness of 2 inches. This partition has been used in a number of buildings in Washington.

Metropolitan Fireproofing Company's Partition.—A partition now being used by The Metropolitan



TYPICAL SECTION OF WOOD TRIM

Fig. 178.—Roebling Partition.

Fireproofing Company is shown by Fig. 180 and is described as follows:

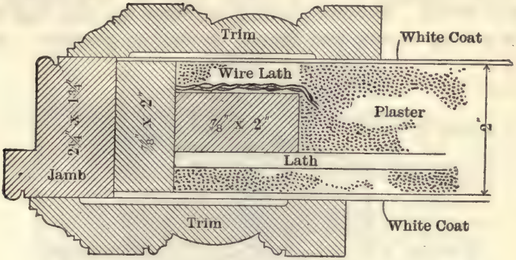


FIG. 179.

A newly patented fire-proof partition which is formed with 2-inch solid blocks of their fire-proof material, which has been fully demonstrated to be effectively fire-resisting, as well as fire-proof.

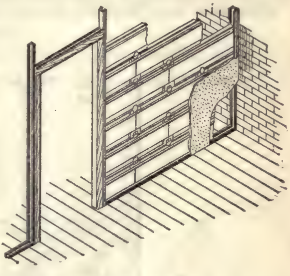


FIG. 180.

The partition is quickly put in place, can be finished and plastered at once, requires no upright studs to support it, holds nail well, and is when finished not over 3 inches thick.

Phœnix Wall Construction.—Fig. 181 shows a terra-cotta partition called the "Phœnix" which is put up by Henry Maurer & Son, New York. The terra-cotta blocks have dovetail recesses on the sides to receive the plaster, and the partition is reinforced in each horizontal joint with a strip of band iron set in the terra-cotta as shown.

The Berger Fire-proof Partition.—This partition, as shown by Fig. 182, is made of expanded-metal lath fastened to a metal stud, which is made as shown, having prongs cut and bent out and which are used to fasten the lath to the stud. This partition is plastered on both sides solid.

Furring, Beams, etc.—Figs. 183 and 184 show one of the usual methods used to fur out beams, build false beams, etc. A piece of channel iron is bent the desired shape and fastened

to the beam or floor above. These ribs are usually spaced about 12 inches apart, then at each angle a $\frac{1}{4}$-inch rod is run along and wired to the ribs, and over this frame the metal lath is bent and wired. The superintendent must see that this framework is put up secure and braced as well as possible. A good

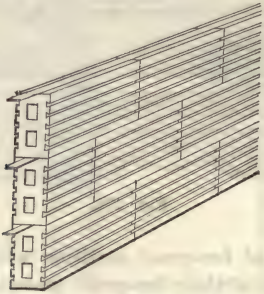


FIG. 181.—Method of Construction of the "Phœnix" Wall, 4 inches thick, with band iron between the courses. Size of blocks, 4×8×12 inches.

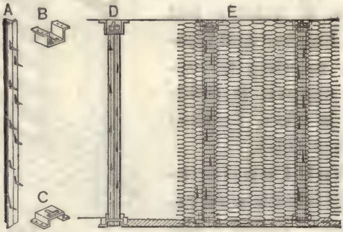


FIG. 182.—*A* shows Stud with Prongs; *B* and *C*, Top and Bottom Sockets; *D*, Stud in Position ready for Lath; *E*, Lath Attached to Stud by clinching down Prongs.

way to fasten the ribs is to run them up through the floor construction and turn them over into the concrete.

Architectural Terra-cotta.—Terra-cotta is used for the ornamentation and trimmings of buildings, taking the place of brick and stone to a great extent. It is made in various shades and colors, from white to deep red or brown, and is usually colored by means of chemicals, so that any color desired can be obtained.

The duty of the superintendent, where terra-cotta is used, will be to see that the blocks of terra-cotta, design, etc., con-

form to the details, that it is the desired color, and that each piece is in perfect condition. In setting, he should take the same precautions as with stone, and in addition to this see

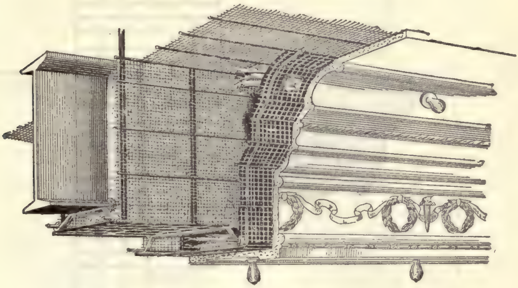


Fig. 183.

that every piece is anchored properly and tied to the structural iron provided for that purpose.

Where any weight will rest on any hollow block, it should be filled with brick and mortar. Care must also be taken to

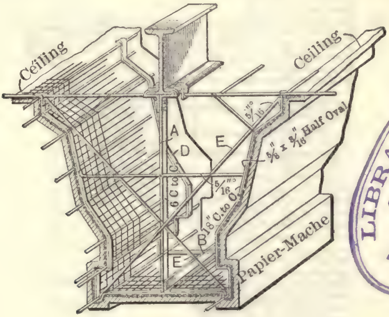


Fig. 184.

have all the joints filled with mortar so there will be no chance for the water to get into them.

Terra-cotta should always be set in strong cement mortar and each block thoroughly wet before being set.

Any blocks twisted or warped in burning, and which cannot be set straight or in line, should be rejected.

As soon as any terra-cotta is set it should be boxed in so as to prevent any damage being done to it by anything falling on it.

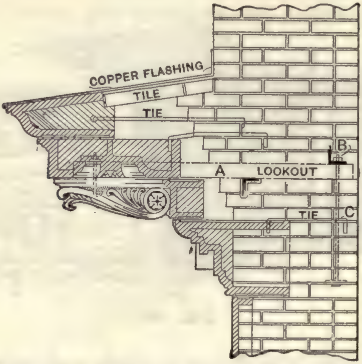


Fig. 185.—Section through a Main Cornice.

Lookouts *A* held down by continuous L, *B*, and rods *C*. *D* is a wall plate. Modillions are suspended from lookouts *A* by means of clips and hangers.

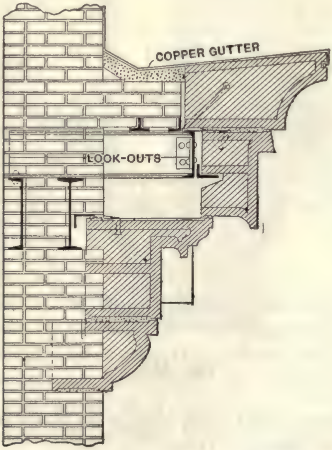


Fig. 186.—Section through a Main Cornice.

Figs. 185–188 show some typical methods of terra-cotta construction.

Fire-proof Construction and Fire Protection of Buildings.—It may not be amiss in introducing the follow-

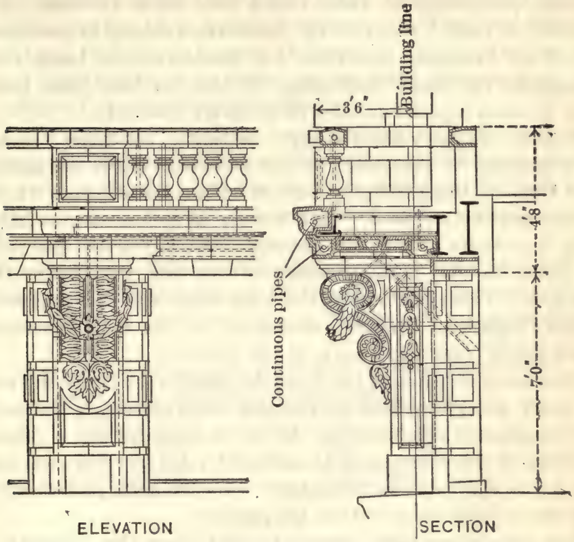


FIG. 187.—Details of Construction for a Central Pavilion.

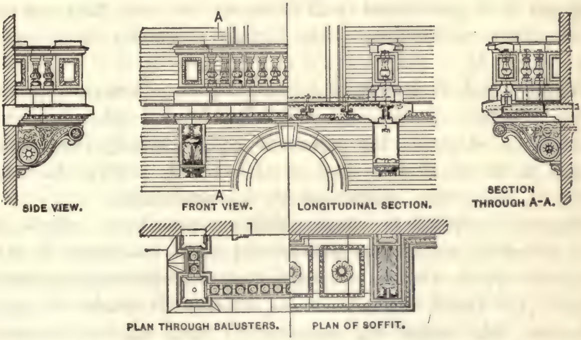


FIG. 188.—Suggestion for a Terra-cotta Balcony.

ing suggestions with regard to the installation of fire-proof construction to say a word regarding the general importance of the subject so far as building methods in the United States are concerned.

The annual fire loss, that is to say that portion of it paid by insurance companies in this country, is not far from $150,000,000, a large percentage of which might be readily avoided. As a matter of fact corresponding losses are avoided in practically all of the European countries, the fire loss abroad being but a comparatively small percentage of the fire loss here, taking into account equal amounts of property insured.

It is a customary error to speak of loss by fire being "covered by insurance." The falsity of this statement lies in the assumption that anything actually burned up can be restored, whereas it can only be replaced. As a matter of fact insurance indemnity represents merely an amount collected from the public at large for the reimbursement of the few who suffer from fire loss. This does not in the least alter the fact that every dollar's worth of property consumed by fire is just so much annihilated from the wealth of the country.

Due consideration of the foregoing should bring to the mind of every superintendent of building construction a realization of the personal responsibility devolving upon him as a valuable member of the community to administer his office in such manner as to eliminate in the largest measure such probability of fire loss as may come within his province.

Too strong emphasis cannot be laid upon the necessity for the superintendent to administer his office in such manner that the work performed shall be consistent with the most rigid of specifications looking to the highest immunity from loss by fire.

While failure to live up to specifications is always reprehensible, it is to be questioned whether if in any other branch of building construction the results of comparatively insignificant omissions or remissions may so thoroughly nullify the whole effort as in matters pertaining to fire protection.

Materials depend for their efficiency first upon wise design and honest manufacture, and second upon intelligent installation, and it is to the latter branch that the following suggestions relate. In these suggestions no attempt is made at logical sequence, but rather an endeavor to place at the disposal of the superintendent certain data which may prove of immediate and practical value.

Fire Protection of Buildings.—In taking up this subject it is the aim of the author to point out and show some of the points in building construction of the present day that

are defects, inasmuch as they are liable to cause a fire or to assist it when once started.

The superintendent should be always on the lookout during the construction of a building for any of these defects and should see that every part of the work is so done that it will render the building fire-proof, or as near fire-proof as the character of the building will allow.

In the ordinary dwellings and the smaller buildings there is often very little care taken on this point, and there is no doubt that many a house or building has been destroyed by fire which gained its start through the neglect of some superintendent, architect, builder, or workman.

FRAME-HOUSE PROTECTION, FLUES, ETC.—We will take, for instance, the ordinary frame house with brick chimneys, which are usually built, as shown by Fig. 189, with 4 inches of brick-

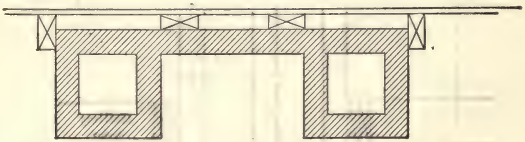


FIG. 189.

work around the flues and back of the fireplace. The studs are set tight against the brickwork as shown, and the floor trimmers are usually framed tight against the sides of the chimney. Now all this wood is but 4 inches or the width of a brick from the flue or fire, and how easy it is for a mason to overlook a "dry" joint or leave a little hole through this 4-inch wall, thus giving the fire a chance to get through. A chimney may be built this way and have such defects and be in use for a number of years and no harm result; then the flue may become lined with soot, which may at any time "burn out," when, if there should happen to be a hole or dry joint, the flame or sparks may be drawn through and set fire to the building. Then often when there is but a 4-inch back wall to a chimney and fireplace and the grate tile are set tight against the back wall the heat from the grate will be carried through and may be the means of setting fire to the studding behind the chimney.

All chimneys should either have 8 inches of brickwork around all outside walls of the flues, as shown by Fig. 190, or else have terra-cotta flue lining, and when flue lining is used the back

wall of the fireplace should be made 8 inches, or at least 6 inches, by setting a course of brick on edge and thus breaking joints with the back 4-inch wall. The flue lining should be carried up through the roof, or better still, to the top of the chimney.

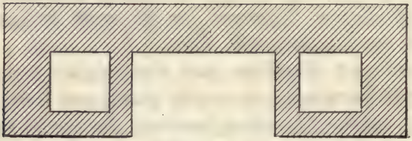


Fig. 190.

Another weak point so far as fire protection is concerned in the ordinary house is where the flues are drawn together at the ceiling joist. Fig. 191 shows how this is usually done.

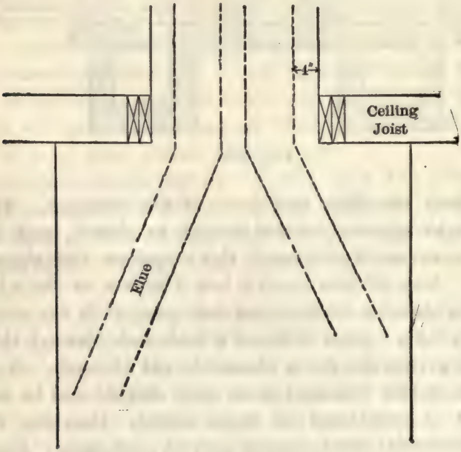


Fig. 191.

The main part of the chimney is cut off so that the ceiling joist will run across the top and frame around the flues, which are drawn together as shown.

This again leaves but 4 inches of brickwork between the flue and the wood joist, and as many a house has been destroyed by a fire starting in the attic, no doubt but some of the fires started at this point The brickwork around the flues should

be carried up 8 inches until the chimney passes through the roof as shown by Fig. 192; then if desired it can be drawn in

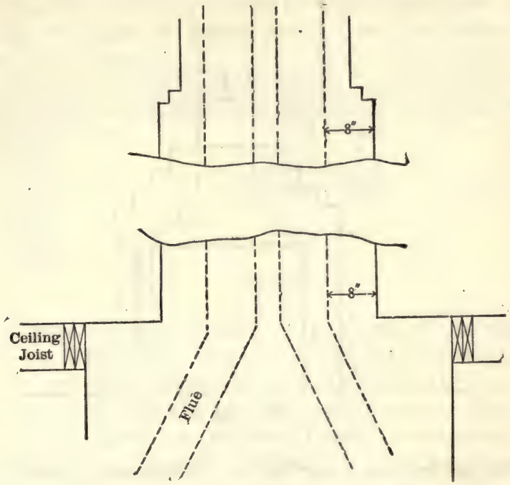


Fig. 192.

as shown, making a much better looking top than if there was no base to it.

Hearth Bottoms.—Another point not to be overlooked is the common method of putting in wooden hearth bottoms, as shown by Fig. 120, page 87. This should not be allowed unless the wall is corbelled out as described by Fig. 121, page 87.

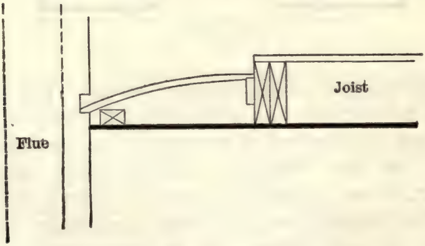


Fig. 193.

A brick arch or corrugated metal bent to a radius, as shown by Fig. 193, is much to be preferred.

STUDDED FIREPLACES.—A cheap form of chimney which has been used throughout California and the South is shown by

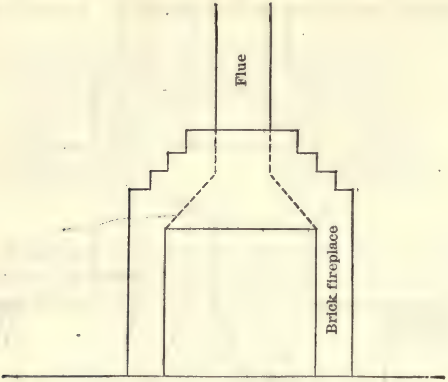


FIG. 194.

Fig. 194, the fireplace being built up of brick and drawn in at the top as shown; then a terra-cotta, or in some cases a sheet-iron pipe is run up for a flue. The fireplace and chimney is then studded around and plastered, as shown by Fig. 195, so as to give

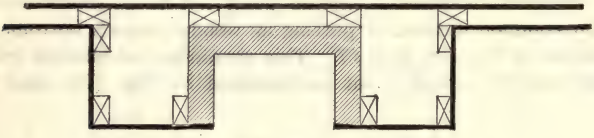


FIG. 195.

it the appearance of a large chimney-breast. This arrangement is nothing more or less than a fire-trap and should never be used.

Regarding this method of construction around fireplaces and chimneys, the San Francisco Building Code says:

"Sec. 21. When a chimney-breast is furred out, the space between the chimney and the breast shall be so built that the passage of fire and smoke shall be intercepted."

This section of the Building Code states that the space shall be built so as to intercept the fire, but the only reliable way is to build a brick chimney and have no blank spaces.

CLOSETS AS FIRE-TRAPS.—In brick and frame houses the space along the side of the room formed by the projection or jamb of the chimney is usually utilized for a closet, as shown by Fig. 196, and the closet is usually furred down and ceiled a few

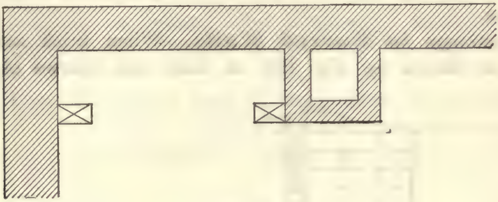


FIG. 196.

inches above the door height. The sides of the flues are usually but 4 inches thick as shown, and the woodwork of the closet is put tight against the chimney, and the space thus formed above the closet is shut off from all access. This woodwork in time becomes so dry that a spark would set it on fire or possibly it would catch fire from the heat from the flue.

This is considered by the author a very weak point in the ordinary house construction, so far as fire protection is concerned.

As mentioned before, the flues should either be lined with flue lining or the outside walls made 8 inches thick.

Chimneys and Flues in Frame Buildings.—The following instructions regarding the construction of chimneys are given in the Building Code prepared by the National Board of Fire Underwriters:

MATERIAL.—All chimneys in frame buildings shall be built of brick or stone or other fire-proof material.

THICKNESS OF BRICKWORK.—If of brick the flues shall have walls at least eight inches thick, except where flues are lined with burnt-clay pipe, in which case the walls around flues may be four inches thick.

HEIGHT FOR FLUE LININGS.—All flue linings shall extend at least one foot above the roof-boards.

WHEN CHIMNEYS ARE OF STONE.—Where chimneys are built of stone the walls of the flues shall be not less than eight inches on all sides, and shall be lined with burnt-clay pipe.

HEIGHT FOR CHIMNEYS.—All chimneys shall be topped out at least four feet above the highest point of contact with the roof, and be properly capped.

PARTY-WALL CHIMNEYS.—Chimneys in party walls or serving two rooms on the same floor may be built in the walls or partitions.

INDEPENDENT CHIMNEYS. — Elsewhere, they shall be built inside of the frame, except in the case of ornamental or exposed chimneys

Fire-stops in Furred Walls.—When brick walls are furred, as shown by Fig. 197, at least two courses of brick

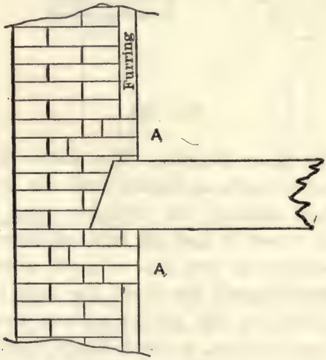


FIG. 197.

should be set out the full thickness of the furring, to form a fire-stop, both above and below the joist as shown at *AA*. If wood furring is used the plate can be set on this projection and the cap under, and wire lath should be used over the brick to prevent the plaster from cracking.

Wooden Nailing-plugs.—Another bad piece of work is the ordinary method carpenters have of driving wooden plugs in the joints of the brickwork of a chimney to nail the base to or to fasten the mantel. The author once saw a mantel take fire from this cause; the wooden plug caught fire and burned out, setting fire to the mantel. The base can always be fastened by nailing into the joints of the brickwork, or if the mortar will not hold the nail, metal wall plugs can be put in and the base nailed to the plugs. Mantels can be hung by driving hooks into the joints of the brickwork and the mantel hung to these hooks by eyes or staples screwed on the back of the mantel.

Bridging as Fire-stops in Partitions. — Where wooden partitions are used, whether inside or outside, and which

rest on the sill, they should have a row of solid bridging cut around at the floor level, as shown at *A*, Fig. 198, and if the studs run through two stories they should be bridged at the ceiling and floor levels, as shown at *B*, Fig. 198; this prevents any draught or suction up the partitions in case of fire. The joist should also be bridged solid along every partition, so in case of fire to keep it from spreading under the floor between the joist.

A method of framing used in some parts of the country, especially on the Pacific Coast, is one in which each story of a building is framed separate, as shown by Fig. 199. For fire

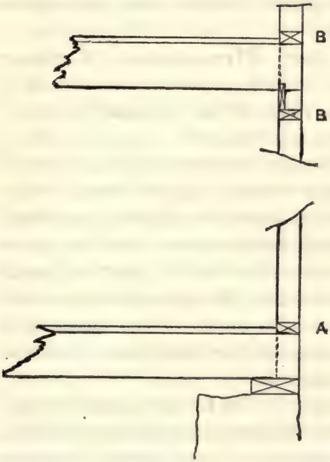


Fig. 198.

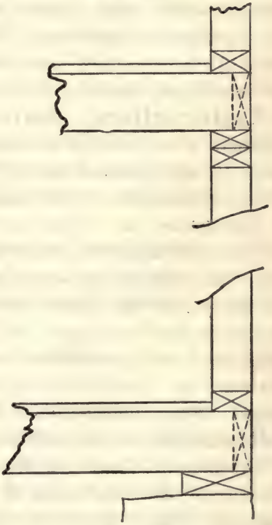


Fig. 199.

protection this is a very good method, as the plates and caps of the walls and partitions cut each story off separate from the others and there is no chance for fire to follow up the inside of the walls. Also see Brick-nogging, page 87.

Regarding this method of construction the San Francisco Building Code says:

"Sec. 19. When stories are framed separately, each tier of studding must have top and bottom plates, and the top plates must be doubled; when stories are not framed separately, proper bridging must be placed behind the ribbon at the

ceiling line and on top of the joist at the floor line. Bridging must be two inches thick and of the full width of the studding in every case.

"Sec. 20. BRIDGING.—All stud-walls, or partitions hereafter built, altered, or repaired, shall have one row of bridging for every seven feet in height over the first seven feet. Said bridging shall in all cases extend to the lathing or sheathing, so as to prevent the passage of fire and smoke, and shall be the same thickness as the studding. All outside walls and cross partitions shall be thoroughly and angle braced; all joists shall have solid end blocking. All buildings over twenty-five (25) feet in width shall have a row of solid blocking over girder or partition of stairways. A row of cross bridging at least two (2) inches thick must be placed between the floor-joists at least every twelve (12) feet."

Underwriters' Rules for Fire-stops.—A better method is to build a fire-stop of brick or other incombustible material as recommended by the rules of the National Board of Fire Underwriters, which reads as follows:

FIRE-STOPS AT ENDS OF BEAMS, IN STUD-WALLS, AND IN PARTITIONS RESTING OVER EACH OTHER.—In all frame buildings which are to be lathed and plastered or otherwise sheathed on the inside, the spaces between such parts of the floor joist or beams that rest upon the stud-walls or upon partition heads shall be filled in solid for the depth of the joist or beams and between the studs or uprights to the depth of the latter to a height of six inches above the top of the floor joist or beams with suitable incombustible materials.

HORIZONTAL BODY OF MATERIAL.—The fire-stop shall extend around all the stud-walls of the building, supporting the filling material where necessary on strips of wood nailed between studs, and in all stud-partitions that rest directly over each other, and thus form a horizontal line of incombustible material to effectually cut off draft openings from story to story through floors, stud-walls, and partitions.

The Building Code of the National Board of Fire Underwriters gives the following rules regarding chimneys, flues, heating-pipes, etc., and which will be a good guide for the superintendent:

CHIMNEYS, FLUES, FIREPLACES, AND HEATING-PIPES.

Sec. 64. Trimmer-arches.—*To Support Hearths.*—All fireplaces and chimney-breasts where mantels are placed, whether intended for ordinary fireplace uses or not, shall have trimmer arches to support hearths.

Width of Trimmer-arches.—And the said arches shall be at least twenty inches in width, measured from the face of the chimney-breast, and they shall be constructed of brick, stone, or burnt clay.

Length of Trimmer-arches.—The length of a trimmer-arch shall be not less than the width of the chimney-breast.

Wood Centres under Trimmer-arches.—Wood centres under trimmer-arches shall be removed before plastering the ceiling underneath.

Hearth under Heater.—If a heater is placed in a fireplace, then the hearth shall be the full width of the heater.

Mantels.—All fireplaces in which heaters are placed shall have incombustible mantels.

Woodwork Back of a Summer-piece.—No wood mantel or other woodwork shall be exposed back of a summer-piece; the iron-work of the summer-piece shall be placed against the brick or stone work of the fireplace.

Fire-boards.—No fireplace shall be closed with a wooden fire-board.

Sec. 65. Chimneys, Flues, and Fireplaces.—*Joints Struck Smooth.*—All fireplaces and chimneys in stone or brick walls in any building hereafter erected, except as herein otherwise provided, and any chimney or flues hereafter altered or repaired, without reference to the purpose for which they may be used, shall have the joints struck smooth on the inside, except when lined on the inside with pipe.

Parging of Flues Prohibited.—No parging mortar shall be used on the inside of any fireplace, chimney, or flue.

Fireplace Backs, Thickness of.—The fire-backs of all fireplaces hereafter erected shall be not less than eight inches in thickness, of solid masonry.

Lining Behind Grate in Fireplace.—When a grate is set in a fireplace, a lining of fire-brick, at least two inches in thickness, shall be added to the fire-back, unless soapstone, tile, or cast iron is used, and filled solidly behind with fire-proof material.

Thickness for Smoke-flues of Boilers, Furnaces, etc.—The stone or brickwork of the smoke-flues of all boilers, furnaces, bakers' ovens, large cooking ranges, large laundry stoves, and all flues used for a similar purpose shall be at least eight inches in thickness, and shall be capped with terra-cotta, stone, or cast iron.

Inside of Flues for Boilers.—The inside four inches of all boiler-flues shall be fire-brick, laid in fire mortar, for a distance of twenty-five feet in any direction from the source of heat.

Smoke-flues of Steam-boilers.—All smoke-flues of smelting-furnaces or of steam-boilers, or other apparatus which heat the flues to a high temperature, shall be built with double walls of suitable thickness for the temperature with an air space between the walls, the inside four inches of the flues to be of fire-brick.

Height for Smoke-flues.—All smoke-flues shall extend at least three feet above a flat roof and at least two feet above a peak roof.

Tops of Chimneys on Three-story Dwellings and Stables.—On dwelling-houses and stables three stories or less in height not less than six of the top courses of a chimney may be laid in pure cement mortar and the brickwork carefully bonded and anchored together in lieu of coping.

CHIMNEYS, FLUES, AND FIREPLACES.—*Smoke-flues to be Lined with Cast-iron or Clay Pipe.*—In all buildings hereafter erected every smoke-flue, except the flues hereinbefore mentioned, shall be lined continuously on the inside with cast-iron or well-burnt clay, or terra-cotta pipe, made smooth on the inside, from the bottom of the flue, or from the throat of the fire-place, if the flue starts from the latter, and carried up continuously to the extreme height of the flue.

Ends of Lining Pipe to Fit Close.—The ends of all such lining pipes shall be made to fit close together, and the pipe shall be built in as the flue or flues are carried up.

Brickwork.—Each smoke-pipe shall be inclosed on all sides with not less than four inches of brickwork properly bonded together.

FLUES TO BE LEFT CLEAN AT COMPLETION OF BUILDING.—All flues in every building shall be properly cleaned and all rubbish removed, and the flues left smooth on the inside upon the completion of the building.

SEC. 66. CHIMNEY SUPPORTS.—*Forbidding Supports of Wood.*—No chimney shall be started or built upon any floor or beam of wood.

Corbelling.—In no case shall a chimney be corbelled out more than eight inches from the wall, and in all such cases the corbelling shall consist of at least five courses of brick.

Corbelling in Eight-inch Walls.—But no corbelling more than four inches shall be allowed in eight-inch brick walls.

Piers Supporting Chimneys.—Where chimneys are supported by piers, the piers shall start from the foundation on the same line with the chimney-breast, and shall be not less than twelve inches on the face, properly bonded into the walls.

Supports for Chimneys Cut Off Below.—When a chimney is to be cut off below, in whole or in part, it shall be wholly supported by stone, brick, iron, or steel.

Unsafe Chimneys—All chimneys which shall be dangerous in any manner whatever shall be repaired and made safe or taken down.

Sec. 67. CHIMNEYS OF CUPOLAS.—*Foundry Cupolas.*—Iron cupola chimneys of foundries shall extend at least ten feet above the highest point of any roof within a radius of fifty feet of such cupola and be covered on top with a heavy wire netting.

Distance for Woodwork.—No woodwork shall be placed within two feet of the cupola.

Sec. 68. HOT-AIR FLUES, PIPES, AND VENT-DUCTS.—*Hot-air Flues to be Lined.*—All stone or brick hot-air flues and shafts shall be lined with tin, galvanized iron, or burnt-clay pipes.

Woodwork not to be Placed against Flues.—No wood casing, furring, or lath shall be placed against or cover any smoke-flue or metal pipe used to convey hot air or steam.

Forbidding Smoke-pipes through Floors.—No smoke-pipe shall pass through any wood floor.

Stovepipes, Distance from Ceilings and Partitions.—No stovepipe shall be placed nearer than nine inches to any lath-and-plaster or board partition, ceiling, or any woodwork.

Metal Shields.—Smoke-pipes of laundry-stoves, large cooking-ranges, and of furnaces shall be not less than fifteen inches from any woodwork, unless they are properly guarded by metal shields; if so guarded, stovepipes shall be not less than six inches distant.

Distance.—Smoke-pipes of laundry-stoves, large cooking-ranges, and of furnaces shall be not less than nine inches distant from any woodwork.

Smoke-pipes through Partitions.—Where smoke-pipes pass through a lath-and-plaster partition they shall be guarded by

galvanized-iron ventilated thimbles at least twelve inches larger in diameter than the pipes, or by galvanized-iron thimbles built in at least eight inches of brickwork.

SMOKE-PIPES THROUGH ROOFS. — *Permit Necessary.* — No smoke-pipe shall pass through the roof of any building unless a special permit be first obtained from the Commissioner of Buildings for the same. If a permit is so granted, then the roof through which the smoke-pipe passes shall be protected in the following manner:

How Protected.—A galvanized-iron ventilated thimble of the following dimensions shall be placed; in case of a stovepipe, the diameter of the outside guard shall be not less than twelve inches, and the diameter of the inner one eight inches, and for all furnaces, or where similar large hot fires are used, the diameter of the outside guard shall be not less than eighteen inches, and the diameter of the inner one twelve inches.

Thimbles.—The smoke-pipe thimbles shall extend from the under side of the ceiling or roof beams to at least nine inches above the roof, and they shall have openings for ventilation at the lower end where the smoke-pipes enter, also at the top of the guards above the roof.

Smoke-pipe of Boiler through Roof.—Where a smoke-pipe of a boiler passes through a roof, the same shall be guarded by a ventilated thimble, same as before specified, thirty-six inches larger than the diameter of the smoke-pipe of the boiler.

HOT-AIR PIPES IN WALLS.—*Covering of Brick or Stone.*—Tin or other metal pipes in brick or stone walls used or intended to be used to convey heated air, shall be covered with brick or stone at least four inches in thickness.

HOT-AIR PIPES IN STUD PARTITIONS.—*Woodwork to be Guarded.*—Woodwork near hot-air pipes shall be guarded in the following manner: A hot-air pipe shall be placed inside another pipe, one inch larger in diameter, or a metal shield shall be placed not less than one-half inch from the hot-air pipe; the outside pipe or the metal shield shall remain one and a half inches away from the woodwork, and the latter must be tin-lined, or in lieu of the above protection, four inches of brickwork may be placed between the hot-air pipe and the woodwork. This shall not prevent the placing of metal lath and plaster directly on the face of hot-air pipes or the placing of woodwork on such metal lath or plaster, provided the distance is not less than seven-eighths of an inch.

Distance from Furnace.—No vertical hot-air pipe shall be placed in a stud partition, or in a wood inclosure, unless it be at least eight feet distant in a horizontal direction from the furnace.

HOT-AIR PIPES IN CLOSETS.—Hot-air pipes in closets shall be double, with a space of one inch between them.

HORIZONTAL HOT-AIR PIPES.—*Distance from Combustible Ceiling.*—Horizontal hot-air pipes shall be placed six inches below the floor-beams or ceiling; if the floor-beams or ceiling are plastered and protected by a metal shield, then the distance shall be not less than three inches.

DUCTS FOR VENTILATION.—*Construction.*—Vent flues or ducts for the removal of foul or vitiated air, in which the temperature of the air cannot exceed that of the rooms, may be constructed of iron or other incombustible material, and shall not be placed nearer than one inch to any woodwork, and no such pipe shall be used for any other purpose.

Material and Thickness of Same in Fire-proof Buildings.—In buildings of fire-proof construction ventilating shafts passing through floors shall be constructed of fire-proof material not less than four inches in thickness. Any opening in such ducts or shafts shall be protected by automatic closing doors or by metal louvres riveted into metal frames, and such ducts shall open to the outside of the building.

VENT-DUCTS IN PUBLIC SCHOOLS.—*How Constructed.*—In the support or construction of such ducts, if placed in a public school-room, no wood furring or other inflammable material shall be nearer than two inches to said flues or ducts, and shall be covered on all sides, other than those resting against brick, terra-cotta, or other incombustible material, with metal lath plastered with at least two heavy coats of mortar, and having at least one-half inch air space between the flues or ducts and the lath and plaster.

Sec. 69. STEAM AND HOT-WATER HEATING PIPES.—*Distance from Woodwork.*—Steam or hot-water heating pipes shall not be placed within two inches of any timber or woodwork, unless the timber or woodwork is protected by a metal shield; then the distance shall be not less than one inch.

Through Floors, how Protected.—All steam or hot-water heating pipes passing through floors and ceilings or lath and plastered partitions shall be protected by a metal tube one inch larger in diameter than the pipe, having a metal cap at the

floor, and where they are run in a horizontal direction between a floor and ceiling a metal shield shall be placed on the under side of the floor over them, and on the sides of wood beams running parallel with said pipes.

Wood-inclosing Boxes to be Lined with Metal.—All wood boxes or casings inclosing steam or hot-water heating pipes and all wood covers to recesses in walls in which steam or hot-water heating pipes are placed shall be lined with metal.

Incombustible Pipes.—All pipes or ducts used to convey air warmed by steam or hot water shall be of metal or other fireproof material.

Pipe Coverings.—All steam and hot-water pipe coverings shall consist of fire-proof materials only.

PLUMBING PIPES PASSING THROUGH FLOORS.—Cold-water or other exposed plumbing pipes shall have the surrounding air space closed off at the ceiling and floor line of any floor through which any such pipe or pipes shall be carried.

Hot-air Pipes.—As the hot-air pipes, etc., are put in position the superintendent should pay close attention and see that the work is done properly, as mechanics often slight this part of the work, thinking it will soon be covered up.

Installation of Heating Plants, etc.—The Building Code of the city of Cleveland gives the following rules for installing heating-plants, steam and hot-air pipes, flues, etc., and will be a good guide for the superintendent.

HEATING.

The subjects under this title include all hearths, pipes, and heating apparatus and their inclosures within a building.

Sec. 1. FLUE CONNECTIONS.—All boilers, furnaces, fireplaces, ovens, and all other heating apparatus mentioned under this title shall be properly connected with a flue chimney or stack as direct and within the shortest distance possible.

This shall include all permanent or temporary heat generators which are used in the erection of a building, and no such heat generator shall hereafter be placed upon the floor or in close proximity to any building which allows the products of combustion to escape directly into the air within twenty (20) feet of any ceiling without being connected with some flue as herein prescribed.

Sec. 2. HEARTHS.—All hearths of fireplaces, irrespective of the fuel used, shall be supported by trimmer-arches of brick, stone, iron, or concrete, or be of single stone at least six (6)

inches thick, built into the chimney and supported by iron beams, one end of which shall be securely built into the masonry of the chimney or an adjoining wall, or which shall otherwise rest upon incombustible support.

The brick jambs of every fireplace or grate opening, independent of the lining, shall be at least one (1) brick wide each, and the back of such openings shall be at least one (1) brick thick. All hearths and trimmer-arches shall be at least twelve (12) inches longer on each side than the width of such openings, and at least twenty (20) inches wide in front of the chimney-breast. Brickwork over fireplaces and grate openings shall be supported by iron bars or brick arches.

The wooden covering in all buildings except those of the VI. and VII. classes under trimmer-arches to be removed before plastering the ceiling underneath.

Sec. 3. Boilers.—*Brick-set.*—No brick-set boiler for the generation of hot water or steam for heating or power or any portable power boiler or engine over ten (10) horse-power shall be placed on any wood or combustible floor or beams.

Sec. 4. Boilers.—*Portable.*—Wood or combustible floors and beams under and not less than three (3) feet in front and one (1) foot on the sides of all portable boilers shall be protected by a suitable brick foundation of not less than two (2) courses of brick well laid in mortar on sheet iron; the said sheet iron shall extend at least twenty-four (24) inches outside of the foundation at the sides and front. Bearing lines of bricks, laid on the flat, with air spaces between them, shall be placed on the foundation to support a cast-iron ash-pan of suitable thickness, on which the base of the boiler shall be placed, and shall have a flange, turned up in the front and on the sides, four (4) inches high; said pan shall be in width not less than the base of the boiler, and shall extend at least two (2) feet in front of it. If a boiler is supported on a cast-iron base with the bottom of the required thickness for an ash-pan, and is placed on bearing lines of brick in the same manner as specified for an ash-pan, then an ash-pan shall be placed in front of the said base and shall not be required to extend under it. All lath-and-plaster and wood ceilings and beams over and up to a distance of not less than four (4) feet in front of all boilers shall be shielded with metal. The distance from the top of the boiler to said shield shall be not less than twelve (12) inches. No combustible partition shall be within four (4) feet of the sides and back and

six (6) feet from the front of any boiler, unless said partition shall be covered with metal to the height of at least three (3) feet above the floor, and shall extend from the end or back of the boiler to at least five (5) feet in front of it; then the distance shall be not less than two (2) feet from the sides and five (5) feet from the front of the boiler.

Sec. 5. Furnaces.—*Brick-set.*—All brick-set hot-air furnaces shall have two (2) covers with an air space of at least two (2) inches between them; the inner cover of the hot-air chamber shall be either a brick arch or two (2) courses of brick laid on galvanized iron or tin, supported on iron bars; the outside cover, which is the top of the furnace, shall be made of brick or metal supported on iron bars and so constructed as to be perfectly tight, and shall be not less than four (4) inches below any combustible ceiling or floor beams.

A single concave iron cover may be used if rigidly supported on the margin and filled with sand to a depth of at least eight (8) inches in the centre and two (2) inches at the edges on all sides.

The walls of the furnace shall be built hollow in the following manner: One (1) inner and one (1) outer wall, each four (4) inches in thickness, properly bonded together with an air space of not less than two (2) inches between them. All brick-set furnaces shall be at least four (4) inches from all wood-work.

Sec. 6. Furnaces.—*Portable.*—All portable hot-air furnaces shall have a double-cased jacket of not less than No. 26 iron from the base to the top of casting, with an air space of at least one (1) inch between, and shall be placed at least two (2) feet from any wood or combustible partition or ceiling, unless the partitions and ceiling are properly protected by a metal shield when the distance shall not be less than one (1) foot. Wood floors under all portable furnaces shall be protected by two (2) courses of brickwork, well laid in mortar on sheet iron. Said brickwork shall extend at least two (2) feet beyond the furnace in front of the ash-pan.

Sec. 7. Cold-air Boxes.—The cold-air boxes of all hot-air furnaces shall be made of metal, brick, or other incombustible material for a distance of at least ten (10) feet from the furnace.

Sec. 8. Ranges.—Where a kitchen range is placed from twelve (12) to six (6) inches from a wood stud partition, the said partition shall be shielded with metal from the floor to the height of not less than three (3) feet higher than the range; if the range is less than six (6) inches from the partition, then the

studs shall be cut away and framed three (3) feet higher and one (1) foot wider than the range and filled into the face of the said stud partition with brick or fire-proof blocks with plaster thereon. All ranges on wood or combustible floors and beams that are not supported on legs and have ash-pans three (3) inches or more above their base shall be set on suitable brick foundations consisting of not less than two (2) courses of brick well laid in mortar on sheet iron, except small ranges that have ash-pans three (3) inches or more above their base, which shall be placed on at least one (1) course of brickwork on sheet iron or cement. No range shall be placed against a furred wall. All lath-and-plaster or wood ceilings over all large ranges, and ranges in hotels and restaurants, shall be guarded by metal hoods placed at least nine (9) inches below the ceiling. A ventilating pipe connected with a hood over a range shall be at least nine (9) inches from all lath and plaster or woodwork and shielded. If the pipe is less than nine (9) inches from lath and plaster and woodwork, then the pipe shall be covered with one-half (½) inch of asbestos plaster or other incombustible covering. No ventilating pipe connected with a hood over a range shall pass through any floor unless protected as prescribed in Sec. 13 for smoke-pipes.

Sec. 9. Laundry-, Cooking-, and Heating-stoves.—Laundry-stoves on wood or combustible floors shall have a course of brick, laid on metal, on the floor under and extended twenty-four (24) inches on all sides of them. All stoves for cooking and heating purposes shall be properly supported on iron legs resting on the floor, three (3) feet from all lath and plaster or woodwork; if the lath and plaster or woodwork is properly protected by a metal shield, then the distance shall be not less than eighteen (18) inches. A metal shield shall be placed under and twelve (12) inches in front of the ash-pan of all stoves that are placed on wood floors.

Sec. 10. Gas-stoves and Ranges.—All low gas-stoves shall be placed on iron stands, or the burners shall be at least six (6) inches above the base of the stoves, and metal guard plates placed four (4) inches below the burners, and all woodwork under them shall be covered with metal. Open gas-stoves shall be isolated in the same manner as provided for stoves in Sec. 9. Gas-ranges, if properly air insulated within themselves, shall be placed one (1) foot distant from all unprotected woodwork or plastered stud partitions.

The use of gas-burners or heaters, located in a floor system under an open register, or on the outside of the fire-pot of any hot-air furnace, in which the products of combustion are allowed to escape into a room, is hereby prohibited, and all such burners or heaters so located shall be removed within thirty (30) days after the passage of this Code.

For gas-fitting and fixtures see Title XXXIX.

Sec. 11. Bake-ovens.—Bake-ovens are to rest on solid foundations or metal beams and columns; the sides and ends shall be at least two (2) feet from any woodwork and the crown of arch at least four (4) feet from ceilings that have wood joists. The hearth in front of bake-oven shall extend at least three and one-half (3½) feet beyond the face of said oven, otherwise all woodwork shall be protected as prescribed for boilers in Sec. 4.

Sec. 12. Core- and Annealing-ovens.—All core- and annealing-ovens, or any portable smelting-furnace, shall be set on incombustible hearths with an air-space of at least five (5) inches between hearths and the bottoms of such ovens or furnaces. The construction of hearths and protection of surrounding woodwork shall be the same as prescribed in Sec. 4 for portable boilers.

Sec. 13. Smoke-pipes.—Where smoke-pipes pass through a wood or plastered stud partition, or furred wall, or floor, they shall be surrounded either by a body of hard, incombustible material, measuring at least four (4) inches all around such smoke-pipe, or they shall be surrounded by a double safety thimble of sheet metal made of two (2) concentric rings of sheet metal at least one (1) inch apart, and the entire thimble so constructed that there will be a circulation of air between the two (2) rings forming the same. No smoke-pipe shall project through an external wall unless connected with a chimney or metal stack carried above the roof.

No stove- or smoke-pipe or any pipe conducting the products of combustion from any range, oven, or heater shall be concealed in any wood partition or be placed nearer than nine (9) inches to any unprotected lath-and-plaster or board partition, ceiling, or any woodwork.

Smoke-pipes of less diameter than twelve (12) inches shall be kept at least twelve (12) inches distant from any woodwork, unless the same is properly protected by a metal shield, in which case the distance shall not be less than three (3) inches.

Smoke-pipes of greater diameter than twelve (12) inches

and less area than six (6) square feet, must be kept at least twenty (20) inches from any woodwork, unless the same is properly protected by a shield, in which case the distance shall not be less than eight (8) inches.

Smoke-pipes of larger area than six (6) square feet shall be kept at least three (3) feet distant from any woodwork, unless the same is properly protected by a shield, in which case the distance shall not be less than sixteen (16) inches.

Sec. 14. Smoke-pipe Shields.—The metal shields prescribed in the previous section shall be at least one and one-half ($1\frac{1}{2}$) the diameter of the pipe in width and shall have a ventilated air-space of at least one (1) inch between shield and woodwork. Incombustible covering, as prescribed in Sec. 19, may be substituted for metal shields, or the smoke-pipe may be covered as prescribed for steam-pipe in Sec. 17.

Sec. 15. Hot-air Pipes.—Hot-air pipes conveying hot air from hot-air furnaces built in between timbers or joists, or through the same, or through wood floors, or in wood partitions or other combustible materials, within ten (10) inches of the same, shall be made double.

The space between the two metal pipes on all sides shall be at least three-eighths ($\frac{3}{8}$) of an inch in the clear, and the two pipes shall be kept apart from each other by the insertion of a sufficient number of metallic separators between, one for every two (2) feet of length of the pipe. Such pipes are to be made with air-tight joints, without soldering them, and shall be securely fastened to the partitions at every two (2) foot interval and at least one-half ($\frac{1}{2}$) an inch from any unprotected woodwork.

No vertical hot-air pipe shall be placed in a stud partition, or in a wood inclosure, unless it be at least one-half ($\frac{1}{2}$) of a diameter of the least dimension of the furnace distant in a horizontal direction from the furnace. Hot-air pipes in closets shall be double, with an air-space as prescribed above, and shall be placed at least one (1) inch from any unprotected woodwork. Horizontal single hot-air pipes shall be placed six (6) inches below the floor-beams or ceiling; if the floor-beams or ceiling are plastered on metal lath or are protected by a metal shield one (1) inch therefrom, then the distance shall not be less than two (2) inches from such ceiling or shield.

When the air conveyed through pipes is heated in an ordinary hot-air furnace, or in any other apparatus by direct contact

of the air with the fire-box, the material used for these double ducts, pipes, and register-boxes shall be bright tin. Where the air is heated with hot-water or steam pipes, any other sheet metal, but of not less gauge than prescribed for tin, may be used for the pipes, and the use of double pipes is not obligatory.

Sec. 16. VENT-PIPES.—Vent flues or ducts for the removal of foul or vitiated air in which the temperature of the air cannot exceed that of the rooms may be constructed of iron or other incombustible material, and shall not be placed nearer than one (1) inch to any woodwork, and no such pipe shall be used for any other purpose.

In the support or construction of such ducts, if placed in a public school-room, no wood furring or other inflammable material shall be nearer than two (2) inches to said flues or ducts, and shall be covered on all sides other than those resting against brick, terra-cotta, or other incombustible material with metal lath, plastered with at least two (2) heavy coats of mortar and having at least one-half (½) inch air-space between the flues or ducts and the lath and plaster.

Sec. 17. STEAM AND HOT-WATER HEATING PIPES.—Steam and hot-water heating pipes shall not be placed within two (2) inches of any timber or woodwork, unless the timber or woodwork is protected by a metal shield; then the distance shall not be less than one-half (½) inch. All steam or hot-water heating pipes passing through floors and ceilings or lath and plastered partitions shall be protected by a metal tube one (1) inch larger in diameter than the pipe, having a metal cap at the floor and ceiling, and where they run in a horizontal direction between the floor and the ceiling they shall be supported on iron and a metal shield shall be placed on the under side of the floor over them, and on the sides of wood beams running parallel with said pipes; or said horizontal pipes shall be covered with incombustible pipe-covering at least three-quarters (¾) of an inch thick. In no case shall lateral branches from rising lines to radiators or coils be allowed between any floor and ceiling line when such laterals cut into or through joists or beams in conflict with Sec. 5, Title XIII; and when such pipes are inaccessibly concealed, they shall be covered with incombustible material, as provided in Sections 18 and 19.

Sec. 18. WOOD CASINGS.—All wood boxes or casings inclosing steam or hot-water heating pipes, and all wood coverings to recesses in walls, in which steam or hot-water heating pipes

are placed, shall be lined with metal, or said pipes shall be covered with incombustible sectional pipe-covering at least three-quarters (¾) of an inch thick.

Sec. 19. Incombustible Pipe-covering.—No concealed pipe shall be covered with a covering whose non-conductivity depends upon cork, felt, or any other organic matter.

All coverings of heated surfaces, or surfaces requiring to be protected from heat, and all concealed or inaccessible steam or hot-water pipes, and all cold and ice water pipes, or other pipes, as prescribed in Sec. 12, Title XII, in buildings having iron frames, shall be made of standard fire-resisting covering, either of magnesium carbonate, calcium carbonate with binders of asbestos fibre, or asbestos fibre and sheet coverings.

Sec. 20. Ducts for Pipes.—All ducts for hot-air, steam, or hot-water pipes shall be inclosed on all sides with fire-proof material, and the opening through each floor shall be properly fire-stopped.

Sec. 21. Registers.—Registers located over a brick furnace shall be supported by a brick shaft built up from the cover of the hot-air chamber; said shaft shall be lined with a metal pipe, and all wood beams shall be trimmed away not less than four (4) inches from it. Where a register is placed on any woodwork in connection with a metal pipe or duct, the end of the said pipe or duct shall be flanged over on the woodwork under it. All registers for hot-air furnaces placed in any woodwork or combustible floors shall have stone or iron borders.

All register-boxes shall be made of tinplate or galvanized iron with a flange on the top to fit the groove in the frame, the register to rest upon the same; there shall be an open space of two (2) inches on all sides of the register-box, extending from the under side of the border to and through the ceiling below. The said opening shall be fitted with a tight tin or galvanized-iron casing, the upper end of which shall be turned under the frame. When a register-box is placed in the floor over a portable furnace, the open space on all sides of the register-box shall be not less than three (3) inches. When only one register is connected with a furnace said register shall have no valve.

Register-boxes, heads, or collars in floors or walls shall be made double and set flush with floor or plaster line.

Sec. 22. Notice as to Heating Apparatus.—In cases where hot-water, steam, hot-air, or other heating appliances or furnaces

are hereafter placed in any building, or flues or fireplaces are changed or enlarged, due notice shall first be given to the Department of Buildings by the person or persons placing the said furnace or furnaces in said building, or by the contractor or superintendent of said work.

Sec. 23. Boiler-rooms.—No boiler for the generation of power shall be placed in any building of the VII. class if of greater capacity than ten (10) H.P. Boilers of more than ten (10) and less than seventy-five (75) horse-power shall not be located within eight (8) feet of any building of the VII. class; if of more than seventy-five (75) and less than two hundred and fifty (250) horse-power they shall be at least twenty (20) feet distant from any building of this class, and if of greater capacity than two hundred and fifty (250) horse-power, they shall not be less than thirty (30) feet distant.

Boiler- and fuel-rooms and smoke-houses which may hereafter be constructed shall be located not less than eight (8) feet distant from any other building and shall be built throughout of incombustible material. All the openings to such boiler- and fuel-rooms and smoke-houses. if same are located within thirty (30) feet of any other building, shall have shutters and doors of metal, or wood covered with metal on both sides and edges.

Boiler- and fuel-rooms, when constructed in buildings shall be separately inclosed in brick walls so arranged that all openings between them and other parts of the building will be securely closed with fire-doors at the end of each day's work.

Sec. 24. Drying-rooms.—All walls, ceilings, and partitions inclosing drying-rooms, when not made of fire-proof material shall be wire-lathed and plastered, or covered with metal, tile, or other hard incombustible material.

Sec. 25. Heating Apparatus in Basements.—All rooms in cellars or basements containing heating-boilers, furnaces, or stoves of any kind, if not constructed of fire-proof material shall have all ceilings lathed and plastered with two (2) coats of brown mortar.

When heating-boilers are used, that portion of the ceiling over the boiler and within a radius of four (4) feet therefrom shall be plastered on metal lath or be protected by incombustible shields.

Sec. 26. Protection against Molten Metal, Hot Liquids, Gases, and Dust.—In every factory or workshop, all machinery

and appliances connected therewith, also every vat, pan, or other structure with molten or hot liquids, shall be placed upon an incombustible foundation or hearth, and shall be constructed in such a manner and so guarded and further protected by such ventilating ducts or pipes as to protect those employed in their operation and use, or about them.

Sec. 27. Ash Boxes and Pits.—All receptacles for ashes shall be of galvanized iron, brick, or other incombustible material. When the ash-pit is located in a basement or cellar it shall have brick walls at least one (1) brick in thickness, and if floor over same is of wood, such pit shall be covered over with either brick arching, stone, or concrete not less than four (4) inches thick with four (4) inches of air-space between the covering of pit and the ceiling, except for pits built directly under the trimmer-arches of hearths.

The ash-flues connected with the upper floors of any building shall be constructed and extend clear up to and above the roof, the same as chimneys.

A self-closing scuppered cast-iron ash-door shall be placed in each story at least two (2) feet above the floor. The metal collar attached to frame shall be at least one-half (½) inch distant from all woodwork and connection with flue made air-tight. Such flues or pits may also be used for sweepings, but for no purpose which would be in violation of the ordinances of the city or the regulations of the Board of Health, and when such flues or pits are built in any building more than two (2) stories high and occupied for any other purpose than a dwelling such ash-pits must have the cleaning-out door accessible from the outside of the building only.

Classification of Fire-proof and Slow-burning Structures.—Highly fire-retardant as well as so-called fire-proof building construction, in structures of any considerable size, may be roughly divided into three classes.

First, mill construction, consisting of brick walls, very heavy solid wooden beams, posts, girders, and flooring, having no concealed spaces or ornamentation; vertical subdivisions such as elevator-shafts, stairways, etc., cut off by brick walls and the whole protected by automatic sprinklers. This type is found principally in the textile mills of New England and the Southern States.

Second, so-called fire-proof buildings having self-sustaining outside walls of brick or stone and interior supporting members

of steel or iron covered with some form of heat insulator, the horizontal sections of which are utilized as flooring.

Third, the so-called steel-cage type of building, consisting of a steel framework of sufficient strength to support the comparatively thin outside walls with which it is veneered, as well as such interior construction as may be essential to floors, partitions, etc.

The first of these types, the mill-constructed building, expressed the outcome of some fifty years of exceedingly expensive experience. This experience has shown that where such buildings are isolated and where specifications such as are furnished by the New England mutual insurance companies are followed the fire loss is reduced to a minimum. Complete description and typical plans, however, can be had gratis upon application to Edward Atkinson, 31 Milk Street, Boston, Mass.

The second type of building, namely the outside supporting walls with iron or steel interior framework, came into existence practically with the invention of the rolled I beam in about 1855.

There is little to say from the fire-protection point of view to the superintendent regarding the construction of outside self-sustaining walls. Their limit of thickness and general details of construction are usually fixed within sufficiently safe limits by local building ordinances, which if followed out consistently should insure satisfactory results.

Coming to the matter of floors, partitions, and other highly fire-resistant interior subdivisons of the second type of building, it may be stated generally that they are very similar in form to corresponding portions of buildings of the third type, while the outside walls, partitions, etc., in the so-called cage-constructed building might, without much stretch of imagination, be considered merely as a vertical flooring inasmuch as each section is sustained upon the general steel framework. In view of the foregoing it is perhaps fair to treat outside walls of the cage type of building as well as interior floor and partition construction in both second and third class of buildings under one heading and make general suggestions for all at once.

As experiments have demonstrated clearly, the steel or iron structural members of a building, while composed of what is commonly regarded as thoroughly fire-proof material, are incapable of withstanding any considerable degree of heat without reducing their mechanical strength to such an extent as to

render them no longer self-supporting, let alone capable of supporting any outside load.

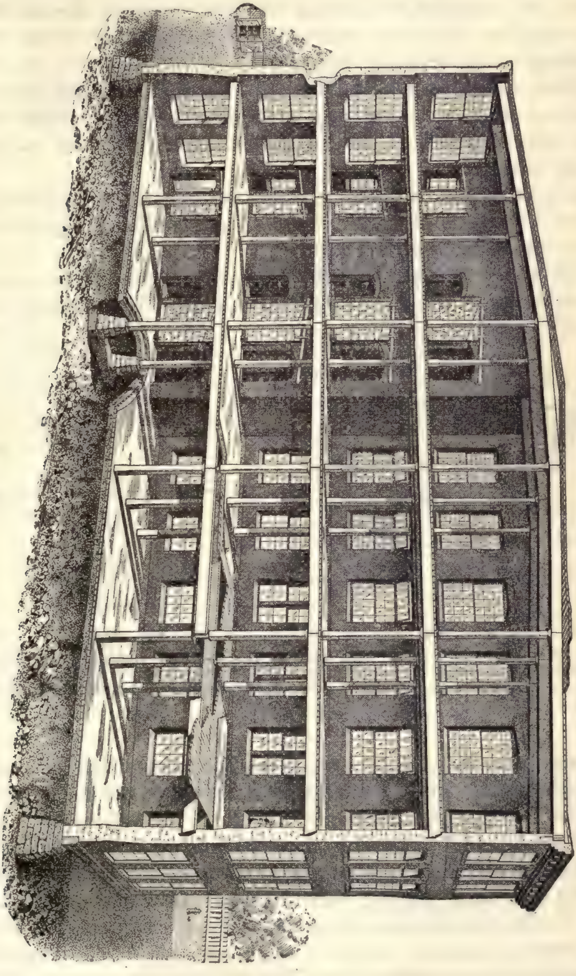


FIG. 200.

As is well known, steel has a comparatively low specific heat and is a good conductor of heat. These, together with the

fact that it loses its mechanical strength at a tremendously rapid rate when heated above 1200° to 1400° F., make exposed-steel construction exceedingly dangerous in the presence of even an insignificant amount of heat, such an amount, for example, as might be generated by the burning of the furnishings of an ordinary room.

Each system has its advantages, its disadvantages, and its partisan advocates, but any great superiority of either over the other depends on care of installation rather than on anything inherent.

To protect iron and steel structural building members from the effect of possible heat, many systems of so-called fire-proof construction have been put forward.

These may be roughly divided into two classes, and in nearly every instance the matter of heat-insulation is combined with

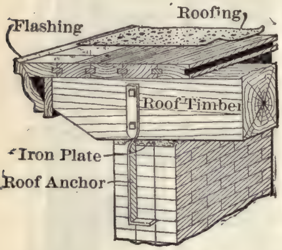


FIG. 201.

Roof-timber resting on cast-iron wall-plate, showing overhanging, open, wood cornice and wrought-iron anchor.

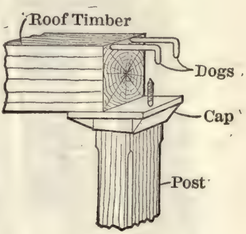


FIG. 202.

Roof-timber resting on column-cap, cast to fit slope of roof. Timbers held together by 1-inch wrought-iron dogs.

a more or less feasible system for the installation of floors, partitions, etc., and in some instances outside walls as well.

The two systems mentioned are, first, some form of baked clay, or moulded plaster or concrete finished in definite forms or blocks and intended for installation in some modification of the arch form. Second, various combinations of steel-supporting members incorporated into and forming a support for a body of Portland-cement concrete, which extends in an unbroken mass from one main structural element to another.

Slow-burning or Mill Construction.—This method of construction, shown by Fig. 200, has been brought into use

through the efforts of the Associated Factory Mutual Fire Insurance Companies of Boston.

While not being in any sense of the word a fire-proof construction, still it affords protection from fire, inasmuch as whatever combustible material is used is so exposed and so put together that it is difficult to cause it to take fire, and when once started it burns slowly and the fire is in plain sight, as there are no hollow walls or spaces to conceal it.

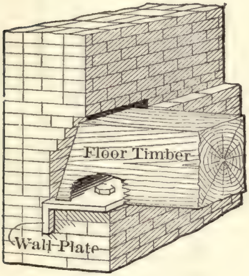


FIG. 203.
Floor-timber resting on cast-iron wall-plates, with lugs for anchoring timber to the wall.

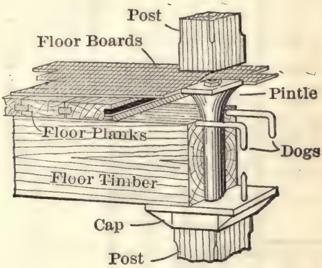


FIG. 204.
Cast-iron cap and pintle for columns and dogs for holding floor-timbers together.

The walls of this class of buildings are usually of brick, with or without piers or pilasters. The floor- and roof-timbers are made heavy enough so that they can be spaced about 8 feet apart, and are carried on wooden posts through the interior of the building. These posts are framed together with a cast-iron pintle, as shown by Figs. 204 and 205.

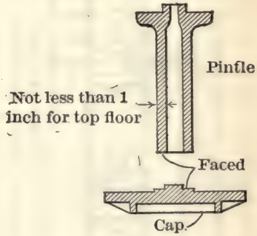


FIG. 205.
Cap and pintle cast to fit columns on each story. Heavy diagonal webs on under side of cap.

Where the floor-timbers or girders rest on the wall they are framed, as shown by Fig. 203, on a cast-iron plate or wall anchor-box.

The floor-timbers are covered with a 3-inch or 4-inch plank floor put together with hard-wood splines, and on top of this is usually laid a matched floor of some hard wood, and in some

cases a double floor is laid on top of the plank floor, the first thickness of flooring being laid diagonally and the top floor laid so as to cross the plank floor.

In this system of construction the main object is to have no concealed spaces for fire to get into, or cause a draught, and

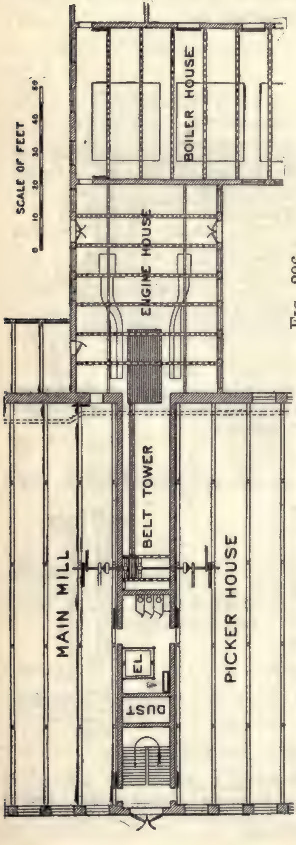


FIG. 206.

PLAN

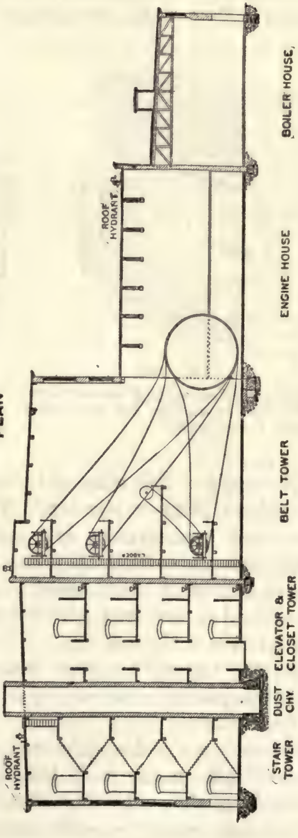


FIG. 207.

SECTION

all timbers connecting with or resting on the walls should be so framed and fastened that if broken or burned off they will readily drop out without injury to the wall. In this construc-

tion each floor is isolated from the others so far as possible, the stairways, belt tower, vent shaft, etc., being cut off with brick walls extending to the roof, as shown by Figs. 206 and 207.

The special features of this method of construction as recommended by the associated factory mutual fire insurance companies are as follows:

1. Walls.—Brick walls at least 1 foot thick in top story and increased in thickness at lower floors to support additional load. The pilastered wall has many favorable features and is often preferred to the plain wall. Window- and door-arches should be of brick, window-sills of sandstone, and door-sills and underpinning of granite.

2. Roofs.—Roofs of 3-inch white pine plank, spiked directly to the heavy roof timbers and covered with 5-ply tar and gravel roofing. Roofs should pitch ½ inch per foot. An incombustible cornice is recommended when there is exposure from neighboring buildings.

3. Floors.—Floors of spruce plank 4 inches or more in thickness according to the floor loads, spiked directly to the floor-timbers. In floors and roof, the bays should be 8 to 10½ feet wide and all planks two bays in length, laid to break joints every 3 feet and grooved for hardwood splines. Usually a top floor of birch or maple is laid at right angles to the planking, but the best mills have a double top floor, the lower one of soft wood laid diagonally upon the plank and the upper one laid lengthwise. This latter method allows boards in alleys to be easily replaced when worn, and the diagonal boards brace the floors, prevent vibration, and distribute the floor load even better than the former method.

Between the planking and the top floor should be two or three layers of heavy tarred paper, laid to break joints, and each mopped with hot tar or similar material to produce a reasonably water-tight as well as dust-tight floor.

Rapid decay of basement or lower floors of mills makes it desirable, whenever wood is not absolutely necessary, to provide cement floors for these places. If wooden floors are required, crushed stone or cinders should be spread evenly over the surface and covered with a thick layer of hot tar concrete, into which an under floor of 2-inch seasoned plank should be pressed and the hardwood top floor-boards nailed across the plank. Cement concretes are apt to promote decay of wood in contact

with them. If extra support is required for heavy machinery, independent foundations of masonry should be provided.

4. Timbers and Columns.—All woodwork in standard construction, in order to be slow-burning, must be in large masses that present the least surface possible to a fire. No sticks less than 6 inches in width should be used, even for the lightest roofs, and for substantial roofs and floors much wider ones are needed. Timbers should be of sound Georgia pine, and for sizes up to 14×16 inches single sticks are preferred, but timbers 7 or 8 inches by 16 are often used in pairs, bolted together with a slight air-space between ($\frac{1}{8}$ to $\frac{1}{4}$ inch). They should not be painted, varnished, or filled for three years because of danger of dry rot, and an air-space should be left in the masonry around the ends for the same reason. Timbers should rest on cast-iron plates in the walls and on cast-iron caps on the columns.

Columns of Southern pine should be bored through the centre by a $1\frac{1}{2}$-inch hole, with $\frac{1}{2}$-inch vent-holes top and bottom, and ends should be carefully squared. They also should not be painted until thoroughly seasoned, to prevent dry rot. Columns should be set on pintles, which may be cast in one piece with a cap, or separately, as preferred. Columns of cast iron are preferred by some engineers, and when the building is equipped with automatic sprinklers have proved satisfactory.

5. Stairs, Elevators, and Belts.—One of the most important features of slow-burning construction is to make the floors continuous from wall to wall without holes for belts, stairways, or elevators, so that a fire may be confined to the floor where it starts. Elevators and stairs, as well as main belts, must be inclosed in brick towers, and all openings provided with self-closing fire-doors. These self-closing doors, as illustrated, should be hung on heavy, inclined, solid-steel rails and balanced by a weight held by a fusible link.

6. Windows.—Windows to be placed as high and made as wide as possible to obtain the best light, and the use of ribbed glass is recommended in upper sashes. In the illustration windows with the ordinary rising sash are shown on the end wall in the upper story, and on the third story the English type, in which the lower sashes may be either fixed or rising, with a transom for ventilation. On the second floor is illustrated a window for wide panels, with a mullion in the centre.

Anchors on Joists, etc.—In mill or factory, and also in

house construction, the specifications will generally specify that the ends of the joists are to be bevelled on the ends 3 inches or 4 inches in the width of the joists. The idea for this is so in case the joists are broken or burned off they will readily drop out of the wall without doing any damage. Then often the same specifications will go on and call for wrought-iron anchors to be built in the wall and securely fastened to every third or fourth joist. These anchors are usually fastened to the sides of the joist and are often put up near the top edge of the joist, which should not be permitted, for if the anchors are fastened at or near the top of the joist and the joist should drop the anchor will either pull in a part of the wall or the lower corner of the end of the joist will force out a portion of the wall. Thus we find the intent of the specifications conflicting, one paragraph tending to release the joists and another fastening them more solid.

When anchors of this kind are used they should be put at the bottom of the joist, and if made of flat iron, as is usual, they should be given a quarter turn at the wall, so the flat of the iron will be in a position to bend easily if the joist should fall.

A more desirable anchor is a cast-iron box in which each joist is set and engaged with lugs, the box being built solid in the wall.

Regarding slow-burning and mill construction the Chicago Building Code says:

Sec. 68. Slow-burning Construction Defined.—The term "slow-burning construction" shall apply to all buildings in which the structural members which carry the loads and strains which come upon the floors and roof thereof are made wholly or in part of combustible material, but throughout which the combustible as well as the incombustible materials shall be protected against injury from fire, by coverings of incombustible, non-heat-conducting material similar to those described under the head of "skeleton construction," except that a single covering of plastering on metal lath and metal furring shall be considered sufficient protection for the under side of joists, and that a deafening of mortar or its equivalent, applied at least one and one-half inches thick, shall be used to cover all floors and roof-surfaces above the joists of the same.

Fire-proof Covering of Posts and Elevator Inclosures—Where oak posts of greater sectional area than one hundred

square inches are used, they need not have special fire-proof covering. All partitions and all elevator inclosures in buildings of this type shall be made entirely of incombustible material. The use of wood furring or of stud partitions shall not be allowed in buildings of this class.

Sec. 69. Mill Construction Defined.—The term "Mill Construction" shall apply to all buildings in which all the girders and joists supporting floors and roof have a sectional area of not less than seventy-two square inches, and above the joists of which there is laid a solid timber floor of thickness not less than three and three-fourths inches thick. Wooden posts used in buildings of this class shall not be of smaller sectional area than one hundred square inches. Partitions and elevator inclosures in buildings of this class shall be made entirely of incombustible material.

Fireproofing.—If iron pillars, girders, or beams are used in buildings of this class, they shall be protected as provided for fire-proof buildings; but the wooden posts, girders, and joists need not be protected by fire-proof covering. The use of wood furring, wood laths, or stud partitions shall not be permitted in buildings of this class.

The following regarding bond iron is taken from the San Francisco Building Code, and the author regards it as an excellent method of construction, as the flat iron gives a bearing for the joist and it also ties the wall together.

Sec. 130. Bond Iron.—Bond iron at least three by one-quarter ($3 \times \frac{1}{4}$) inches shall be placed under each tier of floor and ceiling joists of all brick and stone buildings other than Class "A" and run around the entire walls of the building, and must be lock-jointed and anchored at each angle

Fire Protection of Fire-proof Structures.—It is not the intention of the author, in taking up this subject of fire protection, to advocate any one or more of the many systems of fire-proof construction, or to recommend or condemn either tile or concrete construction, for it is his opinion that either tile or cinder-concrete fireproofing will stand any test of fire that it is liable to be subjected to, providing that the materials and workmanship used are of the best, and the work is done in the best possible manner.

We have only to notice the tests made by various authorities on the different systems of fireproofing to see that nearly all stand the most severe tests; and why? Because when an arch

is built for the purpose of making a test, it is always constructed of the best materials to be obtained, and in the best possible manner.

It is very amusing to read the reports and opinions of the different engineers and architects who visited the scene of some great conflagration, as at Baltimore. One engineer will visit the various buildings that have been damaged by the fire, and according to his report he could see nothing that withstood the fire element but burnt-tile construction; while another engineer will go over the same ground and find that all fireproofing failed except cinder-concrete construction. Then the trade journals will come out, some advocating tile fireproofing, and will publish long articles with photographs showing how tile had stood and concrete failed; while other journals will show that concrete construction had stood and tile had failed; and so to a person not interested in any one method of construction these reports and visits to the scene of the fire show that in places both tile and concrete withstood the hottest fire, and in other places they both failed.

Now, with these facts having but recently been brought before us, it will be the intention of the author to try and show where the work of fireproofing is usually slighted, and where it will be the duty of the superintendent to see that it is done as well as the best materials and workmanship can do it.

Floor Construction of Fire-proof Buildings.—This is one of the most vital points in the construction of a building, and one on which the preservation of the building depends to a great extent in case of fire. Each floor in a building acts as a barrier in case of fire between the different stories, and if the floor construction is weak or fails, then the fire has egress from floor to floor and the fire cannot be confined.

Nearly all the various systems of floor construction now used have been tested and have given excellent results in withstanding heat, except in cases where it has been shown that poor materials and bad workmanship have been used. The Baltimore fire proved that where good materials and workmanship had been used the various systems stood the heat remarkably well, but where bad materials and careless workmanship had been employed they failed.

As the work is so rushed in many instances, and so little care taken in superintending the work, it is little wonder that some buildings fail when put to a fire test.

In all the different methods of floor construction only the very best of materials and labor should be employed, and the work should be done under the direct supervision of a competent superintendent; no matter how good or competent workmen may be they will at times grow careless unless they know some one is watching them.

HOLLOW-TILE CONSTRUCTION.—Hollow tile is one of the oldest systems of fire-proof construction, and has given good results in past fires, where the arches were properly built; but where poor workmanship has been used it failed to stand as it should.

Mortar.—The mortar for setting tile should be made with the best Portland cement, and as Portland-cement mortar is too short or brittle to stick to the tile a little lime putty should be added.

The superintendent should see that just enough of the putty is used to make the mortar plastic enough so that it will stick to the tile as it is shoved into place. Hot lime mortar should never be used.

Setting Tile.—In setting the tile the sides of the beam should first be given a heavy coat of mortar, then the skew-back tile should be coated on the end which sets against the beam, and the tile shoved into place. The succeeding tile should then be coated with mortar on one end and side and shoved into place so as to obtain a solid joint of about $\frac{3}{8}$ inch, as this size joint is heavy enough for all tile-work. The tile used should be of such a size that the key will just fill the space with the above-sized joints; it should not be so tight that it will have to be forced or driven home. If the joints are a little large they should be wedged with a flat piece of tile or slate, but if the proper-sized tile is used this will not be necessary.

When setting tile arches the superintendent should have the workman complete the arch as he goes along. That is, finish each course of tile across the arch and insert the key before starting another course of tile. In side construction, when the tiles overlap and break joints the courses can be stepped back and the key put in place. This method gives the workman a better chance to get the joints slushed full of mortar and also prevents the wooden centre from sagging with the weight of the tile, which is the case when the tiles are all put in and the keys left out until the last.

In floor arches of end construction, if the workmen are not watched they are liable to get the courses of tile out of line, or one tile higher than another, so that the webs of the two adjoining tiles will not butt against each other, as shown by Fig. 208, the shaded section representing the end of one tile and the dotted lines that of the abutting tile.

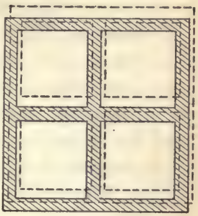


FIG. 208.

An arch built in this manner has very little strength. The webs of each succeeding tile should butt solid against the one already set and all joints should be filled solid with mortar.

After the Baltimore fire it was noticed in some of the buildings that the tile floors of side construction stood better than those of end construction, and no doubt the cause of this was that in the side construction it is easier for the mason to fill his joints than in the end construction, and the end construction mentioned had been slighted. This is one point that the superintendent should bear in mind when superintending any tile-work. After the arch is in place it is well to coat it over with about ½ inch of mortar trowelled smooth, as this insures the filling of all holes and protects the tile.

The webs of tile, to resist fire effectively, should not be less than 1 inch in thickness, and all shoe-tiles for the protection of beams, etc., should be heavy enough so that the beam will be protected with at least 2 inches of tile and mortar, exclusive of the plastering. These shoes should be put on so that they are held in place and supported by the beam and its flange, and no wires should be used to hold them in place.

The lower lips on arch skew-backs are usually 2 inches or less in thickness and form the section of the block most easily chipped off in handling. Even 2 inches of insulation is quite thin enough on the lower flanges of beams and girders, and all chipped skew-backs should be rejected, as patching cannot be done successfully.

Wetting the Tile.—In warm weather all hollow tiles, whether dense or porous, should be well wet or water-soaked before laying. In freezing weather they must be kept dry.

It is good policy to suspend operations and not set any tiles when the weather is so cold as to prevent wetting the tiles.

Dry tiles draw the moisture from the cement mortar and causes it to loose strength.

Concrete Fire-proof Construction.—In fire-proof construction of this kind the main point to be observed is to get good materials. Portland-cement mortar has proven to be one of the best materials to withstand fire, and if the aggregate used to form the concrete is of like material, then there will be no danger of failure from a floor built of this material.

THE AGGREGATE.—Broken brick or tile makes the best aggregate, but on account of the cost is not much used. Broken stone is to be avoided, as stone will not stand the heat. Crushed slag or clinkers make a good aggregate and are entirely fire-proof. Cinders have been, and will be, the principal aggregate used for fire-proof concrete construction, because of its cheapness, and because cinders can be obtained in almost any locality.

In many cases the cinders that have been used to make the concrete have been fireproof in name only, and it is these cases that fail in case of fire. The ordinary cinders usually contain from 50 to 70 per cent of dirt, ash, and unburned coal, and this must all be taken out before it is a fire-proof material. The cinder aggregate should be composed of small or crushed clinkers, and if there is more than 10 per cent of dirt, ash, or unburned coal it should not be used. The superintendent should see that the cinders are so screened, and if necessary, washed, so as to obtain an aggregate of 90 per cent clinkers. A concrete made of this aggregate and Portland cement will withstand any fire it is liable to come in contact with.

PREPARING AND PLACING.—The concrete should be prepared and put in place as described on pages 167 and 174.

When beams, girders, columns, etc., are protected by concrete the concrete should not be less than 3½ inches thick on the outer corners of the beam or column.

USE OF PLASTER OF PARIS.—Any floor construction in which plaster of Paris is used to any large extent should be avoided, or any wall plaster which has plaster of Paris as its base should not be used, as plaster of Paris will not stand excessive heat.

The Building Code of the city of Cleveland prohibits the use of plaster of Paris in the following:

Sec. 1. MATERIALS PROHIBITED.—No plaster of Paris, or sulphate of lime, and no coal, sawdust, coke, coke breese, or unconsumed or partly consumed material, inclusive of cinders, containing any of the compounds of carbon and subject to com-

bustion, disintegration, or distillation at 1500° F., shall enter into any material used for the construction of the floors, partitions, covering for structural members, or in any part of fire-proof buildings of the I. and II. classes, except in the form of wall plastering or as a gauge for mortar. No quicklime shall be used in the composition of the material used in the construction of walls or floors except in combination with Portland cement when used for mortar in setting fire-proof material with a trowel.

Tile Partitions, Furring, etc.—All tile partitions should start directly on top of the floor arch or beam, and should never be built on top of any wood floor or floor strips. The tile should be well anchored to the adjoining walls and joints broken so as to get as rigid a wall as possible.

ARCHES OVER OPENINGS.—Over all openings the tile should be cut so as to form a flat arch, and no dependence should be placed on the frame to carry the tile.

NAILING-BLOCKS.—It has been the custom in the past to build in wood blocks as shown by Fig. 209, for nailing base or grounds to.

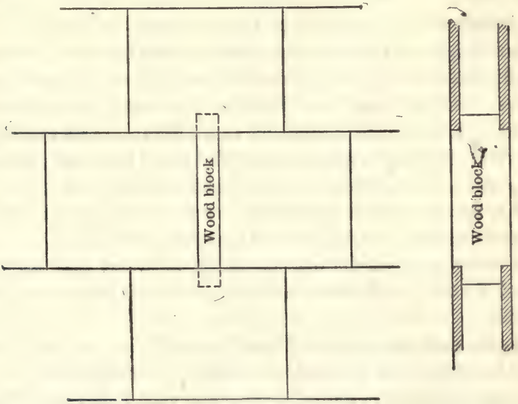


FIG. 209.

Blocks of this kind should not be used, but a wood block can be put inside the tile for nailing purposes as shown and described on page 303.

Casing of Columns, Furring, etc.—When iron or steel columns are furred or cased with tile, the tile should never

be less than 4 inches thick, and all space between the tile and iron should be filled solid with mortar and small pieces of tile, as this in itself is a good protection from fire. The tile should always be put up in such a manner that it will sustain itself, and never be dependent on wires or metal clips of any kind.

Wood in Fire-proof Structures.—During the past few years fire-proof materials have been gradually taking the place of wood in the construction of fire-proof buildings until at the present time all the wood used is in the floors, windows, doors, and trim; and it will be but a short while until all wood will be practically eliminated from any fire-proof structure. Window frames and sash are now made in metal, floors are made of various fire-proof compositions, doors are made of metal or of wood covered with metal, mouldings for trim and base can be made in metal or run in cement, so at the present time it is possible to erect a building that will have no combustible material whatever in its construction. But as construction of this kind means extra cost capitalists and builders will be averse to it unless forced to it by the building laws of the various cities.

By making some changes in the methods used at the present time buildings can be made fireproof and with a small percentage of additional cost. Wood floors when laid on sleepers bedded in concrete afford very poor fuel for a fire, and it would be hard to ignite unless a large amount of other inflammable material was in the room to make a great heat. The wood base can be replaced with a neat cement base at very little extra cost.

The windows should be entirely of metal to afford protection from the outside, as will be explained more fully.

The doors and jambs can be made of wood and the plaster finished to the jamb with a bead or with a stucco or cement moulding. This will give a building with no wood but floors and doors, and the cost will not be much in excess of what it would be with the present methods of construction.

In some buildings erected during the past few years the floors have been laid on strips which were simply laid on the floor-arch, and the space between not filled with concrete but left open.

This should never be permitted, as this space only makes a draught or sort of flue in case of fire. The space should be filled solid to the top of the floor strips with concrete.

Then heavy wood frames have been set in all openings of partitions, etc., and the tile built around them and across the top, the wood frames being depended upon to carry the tile over the opening. This should never be allowed. Wood blocks can be put inside the tile and the door-jambs can be nailed and fastened through the tile into these blocks, or the jamb can be bolted fast with toggle-bolts.

If it is desired to use a rough frame a 2-inch one is heavy enough and should be bolted fast to the tile, and the tile should be arched over the top so as to carry its own weight.

There are several processes by which wood can be rendered fireproof, and all wood used in a fire-proof building should be fireproofed by an approved process.

Pipes, Wires, etc., in Fire-proof Buildings.—In all fire-proof buildings there should be provisions made for taking care of all pipes, conduits, wires, etc., without having them built in the partitions or in the casing of the columns, as is commonly done. A shaft should be built with brick walls extending from the cellar to the roof with outlets at each floor covered with fire-proof doors. The pipes can be carried up in such a shaft and branches taken off to supply each floor; a ladder should be provided the full length of the shaft with platforms at each floor, then the valves or stop-cocks controlling the various branches would be easily accessible. It was claimed by some parties after the Baltimore fire that the pipes encased in the column fireproofing of some of the buildings got so hot they buckled and forced off the fire-proof casing; but if they did it was because the fireproofing gave way or was not heavy enough to protect the pipes or they would not have got hot. Still all pipes should be run up in a shaft where they can be got at any time. When a pipe runs up in a partition or column the mason has to cut his tile around it and this weakens the fireproofing.

Stairways in Fire-proof Buildings.—The stairway or shaft in a fire-proof, or in fact in any brick or other than a frame structure, should be inclosed on all sides with brick walls, and all openings should be provided with fire-proof doors so that the stairway can be shut off from the rest of the building. These doors should be arranged so as to work automatically in case of fire. The stairs should be built of iron or other incombustible material, and if slate or marble treads or platforms are used the slate or marble should be supported under its entire surface

with metal or concrete. Marble and slate will not stand excessive heat, and the treads or platforms are liable to get hot and break in case of fire; this endangers the lives of firemen who may be using the stairs.

The spread of fire in a vertical direction is undoubtedly most effectively guarded against by making the floors continuous and unbroken; that is, eliminating all openings in the floors and placing the necessary means of communication, such as stairways, elevators, pipes, shafts, belts, etc., in shafts entirely separated from the rest of the building by brick walls. Elevator shafts, stairways, and corridors, in buildings where sightliness is an essential, can be thoroughly cut off from the remainder of the building by wire-glass partitions mounted in iron framework. This application is favored in office buildings, hotels, department stores, etc.

The Building Code recommended by the National Board of Fire Underwriters gives the following

RULES FOR FIRE-PROOF CONSTRUCTION.

Sec. 105. Fire-proof Buildings.—*Buildings Named.*—Every building hereafter erected or altered to be used as a theatre, lodging-house, school, jail, public station, hospital, asylum, institution for the use, care, or treatment of persons, the height of which exceeds three stories and not more than forty feet in height, and every building hereafter erected or altered to be used as a hotel or an apartment hotel which exceeds four stories and not more than fifty feet in height, excepting all buildings for which specifications and plans have been heretofore approved by the proper authorities, and every other building the height of which exceeds fifty-five feet or more than four stories in height, shall be built fireproof; that is to say—

Fire-proof Construction Stated.—They shall be constructed with walls of brick, stone, Portland-cement concrete, iron, or steel in which wood beams or lintels shall not be placed, and in which the floors and roofs shall be constructed with rolled wrought-iron or steel floor-beams, spaced not more than five feet on centres and otherwise so arranged as to spacing and length of beams that the load to be supported by them, together with the weights of the materials used in the construction of the said floors, shall not cause a greater deflection of the said beams than one-thirtieth of an inch per foot of span under the

total load; and they shall be tied together at intervals of not more than eight times the depth of the beams with suitable tie-rods.

Floor Filling between Beams.—Between the floor-beams shall be placed brick arches springing from the lower flanges of the steel beams, or the spaces between the beams may be filled with hollow-tile arches of hard-burnt clay or porous terra-cotta, or arches of Portland cement reinforced with metal, or such other fire-proof composition may be used, provided that in each and all cases the strength and method of construction shall be acceptable to the commissioner of buildings.

Stairs.—The stairs and staircase landings shall be entirely of brick, stone, Portland-cement concrete, iron, or steel.

Allowed Woodwork Mentioned.—No woodwork or other inflammable material shall be used in any of the partitions, furrings, or ceilings in any such fire-proof buildings, excepting, however, that when the height of the building does not exceed eight stories nor more than one hundred feet the doors and windows and their frames and trims, the casings, the interior finish when filled solidly at the back with fire-proof material, and the floor-boards and sleepers directly thereunder, may be of wood, but the space between the sleepers shall be solidly filled with fire-proof materials and extend up to the under side of the floor-boards.

When More than Eight Stories or More than 100 *Feet High.*—When the height of a fire-proof building exceeds eight stories, or more than one hundred feet, the floor surfaces shall be of stone, cement, rock asphalt, tiling, or similar incombustible material, or the sleepers and floor-boards may be of wood treated by some process approved by the commissioner of buildings to render the same fire-retarding.

Metal Window Frames and Sash.—All outside window frames and sash shall be of metal.

Inside Woodwork, how Treated.—The inside window frames and sash, doors, trim, and other interior finish may be of wood covered with metal, or of wood treated by some process approved by the commissioner of buildings, to render the same fire-retarding.

Hall and Permanent Partitions of Fire-proof Material.—All hall partitions or permanent partitions between rooms in fire-proof buildings shall be built of fire-proof material and shall not be started on wood sills nor on wood floor-boards, but

be built upon the fire-proof construction of the floor and extend to the fire-proof beam filling above.

Solid Space above Doors and Windows in Partitions.—The tops of all door and window openings in such partitions shall be at least twelve inches below the ceiling line.

Inclosing of Stair Halls.—In all fire-proof buildings other than stores, warehouses, and factories, if exceeding three stories and forty feet in height, the stair halls shall be inclosed on each story with fire-proof material, same as required for elevators, to so form an inclosure the floor area of which shall not be more than three times the united area of the floor openings for the elevators and stairs.

Sec. 106. FIRE-PROOF FLOOR FILLINGS BETWEEN BEAMS.—*Common Brick Arches.*—Between the wrought-iron or steel floor-beams shall be placed brick arches springing from the lower flange of the steel beams.

Rise per Foot of Span.—Said brick arches shall be designed with a rise to safely carry the imposed load, but never less than one and one-quarter inches for each foot of span between the beams, and they shall have a thickness of not less than four inches for spans of five feet or less and eight inches for spans over five feet, or such thickness as may be required by the commissioner of buildings.

How Laid.—Said brick arches shall be composed of good, hard brick or hollow brick of ordinary dimensions laid to a line on the centres, properly and solidly bonded, each longitudinal line of brick breaking joints with the adjoining lines in the same ring and with the ring under it when more than a four-inch arch is used. The brick shall be well wet and the joints filled in solid with cement mortar. The arches shall be well grouted and properly keyed.

Hollow-tile Arches of Burnt Clay or Terra-cotta.—Or the space between the beams may be filled in with hollow-tile arches of hard-burnt clay or porous terra-cotta of uniform density and hardness of burn.

Skew-backs.—The skew-backs shall be of such form and section as to properly receive the thrust of said arch; and the said arches shall be of a depth and sectional area to carry the load to be imposed thereon without straining the material beyond its safe working load, but said depth shall not be less than one and three-quarters inches for each foot of span, not including any portion of the depth of the tile projecting below

the under side of the beams, a variable distance being allowed of not over six inches in the span between the beams if the soffits of the tile are straight; but if said arches are segmental, having a rise of not less than one and one-quarter inches for each foot of span, the depth of the tile shall be not less than six inches.

Joints Filled with Cement Mortar.—The joints shall be solidly filled with cement mortar as required for common brick arches and the arch so constructed that the key parts shall always fall in the central portion.

End Construction.—The shells and web of all end-construction blocks shall abut, one against another.

Arches of Portland-cement Concrete Reinforced with Metal, Segmental in Form.—Or the space between the beams may be filled with arches of Portland-cement concrete, segmental in form, and which shall have a rise of not less than one and one-quarter inches for each foot of span between the beams.

Thickness at Crown of Arch.—The concrete shall be not less than four inches in thickness at the crown of the arch and shall be mixed in the proportions required by Section 18 of this Code.

Reinforced with Metal.—These arches shall in all cases be reinforced and protected on the under side with corrugated or sheet steel, steel ribs, or metal in other forms weighing not less than one pound per square foot and having no openings larger than three inches square.

Various Fillings between Floor-beams — Tests as a Precedent Condition of Use.—Or between the said beams may be placed solid- or hollow-burnt clay, stone, brick, or concrete slabs in flat or curved shapes, concrete or other fire-proof composition, and any of said materials may be used in combination with wire cloth, expanded metal, wire strands, or wrought-iron or steel bars; but in any such construction and as a precedent condition to the same being used, tests shall be made as herein provided by the manufacturer thereof under the direction and to the satisfaction of the Commissioner of Buildings, and evidence of the same shall be kept on file in the Department of Buildings, showing the nature of the test and the result of the test.

How Tests shall be Made.—Such tests shall be made by constructing within inclosure walls a platform consisting of four

rolled steel beams, ten inches deep, weighing each twenty-five pounds per lineal foot, and placed four feet between the centres, and connected by transverse tie-rods, and with a clear span of fourteen feet for the two interior beams and with the two outer beams supported on the side walls throughout their length, and with both a filling between the said beams, and a fire-proof protection of the exposed parts of the beams of the system to be tested, constructed as in actual practice, with the quality of material ordinarily used in that system and the ceiling plastered below, as in a finished job; such filling between the two interior beams being loaded with a distributed load of one hundred and fifty pounds per square foot of its area and all carried by such filling; and subjecting the platform so constructed to the continuous heat of a wood fire below, averaging not less than seventeen hundred degrees Fahrenheit for not less than four hours, during which time the platform shall have remained in such condition that no flame will have passed through the platform or any part of the same, and that no part of the load shall have fallen through, and that the beams shall have been protected from the heat to the extent that after applying to the under side of the platform at the end of the heat test a stream of water directed against the bottom of the platform and discharged through a one and one-eighth inch nozzle under sixty pounds pressure for five minutes, and after flooding the top of the platform with water under low pressure, and then again applying the stream of water through the nozzle under the sixty-pounds pressure to the bottom of the platform for five minutes, and after a total load of six hundred pounds per square foot uniformly distributed over the middle bay shall have been applied and removed, after the platform shall have cooled, the maximum deflection of the interior beams shall not exceed two and one-half inches.

Different Tests may be Prescribed.—The Commissioner of Buildings may from time to time prescribe additional or different tests than the foregoing for systems of filling between iron or steel floor-beams, and the protection of the exposed parts of the beams.

Systems Failing under Test, Use Prohibited.—Any system failing to meet the requirements of the test of heat, water, and weight as herein prescribed shall be prohibited from use in any building hereafter erected.

Authenticated Tests may be Accepted.—Duly authenticated

records of the test heretofore made of any system of fire-proof floor filling and protection of the exposed parts of the beams may be presented to the Commissioner of Buildings, and if the same be satisfactory to said Commissioner it shall be accepted as conclusive.

Protection against Injury by Freezing.—Temporarily Covered over when Necessary.—No filling of any kind which may be injured by frost shall be placed between said floor-beams during freezing weather, and if the same is so placed during any winter month, it shall be temporarily covered with suitable material for protection from being frozen.

Cinder-concrete Filling on Top, to be Filled up to Under Side of Wood Floor-boards.—On top of any arch, lintel, or other device which does not extend to and form a horizontal line with the top of the said floor-beams, cinder concrete, or other suitable fire-proof material shall be placed to solidly fill up the space to a level with the top of the said floor-beams, and shall be carried to the under side of the wood floor-boards in case such be used.

Temporary Centring, when to be Removed.—Temporary centring, when used in placing fire-proof systems between floor-beams, shall not be removed within twenty-four hours, or until such time as the mortar or material has set.

Strength for Fire-proof Floor Fillings—Material to be within Safe Bearing Load.—All fire-proof floor systems shall be of sufficient strength to safely carry the load to be imposed thereon without straining the material in any case beyond its safe working load.

Incasing Exposed Sides and Bottom Flanges of Beams and Girders.—Floor- and Roof-beams.—The bottom flanges of all wrought-iron or rolled-steel floor- and flat roof-beams, and all exposed portions of such beams below the abutments of the floor arches or filling between the floor-beams, shall be entirely incased with hard-burnt clay, porous terra-cotta, or other fire-proof material corresponding to the filling between the beams, such incasing material to be properly secured to the beams.

Girders.—The exposed sides and bottom plates or flanges of wrought-iron or rolled-steel girders supporting iron or steel floor-beams, or supporting floor arches or floors, shall be entirely incased in the same manner.

Pipe Openings through Fire-proof Floors to be Shown on Plans.—Openings through fire-proof floors for pipes, conduits,

and similar purposes shall be shown on the plans filed in the Department of Buildings.

Limited Size for Holes after Floors are in.—After the floors are constructed no opening greater than eight inches square shall be cut through said floors unless properly boxed or framed around with iron;

Openings to be Filled.—And such openings shall be filled in with fire-proof material after the pipes or conduits are in place.

Sec. 107. INCASING INTERIOR COLUMNS.—*Material and Thickness.*—All cast-iron, wrought-iron, or rolled-steel columns, including the lugs and brackets on same, used in the interior of any fire-proof building, or used to support any fire-proof floor, shall be entirely protected with not less than four inches of hard-burnt brickwork, terra-cotta, concrete, or other fire-proof material, securely applied, but no plaster of Paris nor lime mortar shall be used for this purpose.

Lugs and Brackets, Incasing of.—The extreme outer edge of lugs, brackets, and similar supporting metal may project to within seven-eighths of an inch of the surface of the fireproofing.

Prohibiting Pipes, Wires, Conduits, being Placed within Coverings of Columns, Girders, etc.—No pipes, wires, or conduits of any kind shall be incased in the fireproofing surrounding any column, girder, or beam of steel or iron, but shall be placed outside of such fireproofing.

Protection of Buildings from Fire from the Outside.—Until within recent years the aim of architects and engineers in designing fire-proof structures has been to design a building or structure which would be fire-proof against any fire originating within itself, giving very little thought to the protection of the structure from an outside fire.

One of the first instances of a large fire which demonstrated the fact that outside protection was necessary was when the Horne Building in Pittsburg, Pa., was burned in 1897. This building, filled with dry-goods, took fire from the heat of a fire on the opposite side of the street, the contents burned, and the building was gutted and damaged to a great extent. Then in more recent conflagrations the fact has become more evident that a building to be entirely fire-proof must be protected just as much, if not more, from an outside fire as from one within its own walls. The building itself may be constructed entirely of fire-proof materials, yet the contents of the building may be very inflammable, and if not protected from

fire from the outside would become ignited, and in burning do much damage to the building.

SELECTION OF MATERIALS.—The first consideration in the construction of a fire-proof building should be in the selection of the materials to be used, and if the building is to be erected to withstand fire from the outside, then only those materials should be used that are known to be able to withstand fire.

The fire-resisting qualities of brick, stone, etc., are about as follows, with brick ranking first: Brick, plain terra-cotta, concrete, sandstone containing iron, granite, limestone, marble.

The prevailing material of all outside walls should be brick; and stone or granite should not be used above the first or second stories. Granite or stone will not stand excessive heat, and in case of fire the heat above the first story is so intense that stone or granite will not stand. It is possible that in the first story of a building it would pass through a fire unharmed, providing the stone or granite had no sharp corners or projections to spall off.

In the brick it is advisable to have all exposed corners round or chamfered so as to prevent spalling.

No brick wall should be less than 18 inches thick, as a wall of less thickness is liable to crack when exposed to strong heat.

SILLS AND LINTELS.—The sills and lintels of the windows should be of terra-cotta or brick.

Terra-cotta is one of the best of fire-resisting materials, but should be made plain and have few projections and sharp corners. When any terra-cotta is built in the wall it should be backed up and filled solid with brick and mortar.

METAL WALL TIES AND SECRETE HEADERS.—Under no consideration should metal wall ties or secrete headers or bond be used in the walls of any structure that may have to withstand a fire, for the face course of brick, or veneering as it really is, will invariably crack and fall off in case of fire.

POINTING.—The pointing of the joints in the brick- or stone-work should be made concave, for a convex joint will break off in case of fire.

CORNICES.—The cornices of a fire-proof building should be made of terra-cotta or sheet metal, and if sheet metal is used it should be fastened to iron brackets or supports, and in no case should wood be used for this purpose. When terra-cotta is used for cornices or any projections it should be firmly anchored to iron brackets provided for this purpose.

Cement Mortar.—Cement mortar should be used throughout in all walls of a fire-proof building.

Protection of External Openings in Fire-proof Buildings.—The exterior door and window openings of a building are its weakest points in resisting an outside fire, and until recent years these points have received but little attention from architects and engineers when designing a building to be fire-proof.

Frames and sash are now made of metal, and with wire-glass and iron shutters a window or door opening can be so protected that it will withstand a most severe fire.

The metal frames should be made heavy enough and so anchored to the masonry that they will not warp or twist out of shape and let the sash drop out. The sash should be hung with a chain or ribbon that will not melt if it becomes hot, and the chain should be so fastened that there will be no danger of the weight becoming loose in case of fire and permitting the sash to drop.

Lead weights should not be used unless the box in the frame is so protected that the frame will not get hot enough to melt the weights, and thus let the sash drop down.

The glass also should be fastened in such a manner that there will be no danger of it dropping out.

The sash should be glazed with wire-glass not less than $\frac{1}{4}$ inch in thickness, as this offers a very effective resistance to fire; but the author is of the opinion that wire-glass in itself is not a sufficient protection to window openings. In addition to the wire-glass the openings should be provided with iron shutters. The old iron-clad shutter recommended by the National Board of Fire Underwriters has given a good account of itself in recent fires, but it cannot be expected to withstand extreme heat, for the wood will become charred and the metal covering warp out of shape, permitting an egress for flame

Steel shutters should be used on all openings possible, the shutters being made of a single piece of plate not less than $\frac{1}{4}$ inch in thickness, and if any stiffening-bar or frame is used it should be fastened to the plate so as to allow for any unequal expansion between the frame and the plate. The shutters should be arranged so as to allow for expansion, and the fastenings made so that the shutters can readily be opened from the outside in case of fire within.

Where it is not possible to use a plate-shutter, a rolling one

can be used. These shutters are made of corrugated bars of sheet metal riveted and locked together, and when used for fire protection should be made of heavy sheet steel.

The main points to be considered when using metal shutters and doors of any kind are to see that they are fastened securely to the masonry and also that provisions have been made for expansion. The fastenings should be such that they will hold the door or shutter firmly in place and not allow it to warp open.

The following specifications have been accepted by The Chicago Underwriters' Association for metal frames and sash:

THE CHICAGO UNDERWRITERS' ASSOCIATION.

REQUIREMENTS FOR THE ACCEPTANCE OF WINDOWS OF APPROVED WIRE-GLASS IN METALLIC FRAMES AND SASH IN LIEU OF FIRE-SHUTTERS.

FRAMES.—All parts of frame and sash must be made of No. 24 galvanized iron or heavier, and of a quality soft enough to bend without breaking, or 18-oz. copper. Sides so made as to form an air-space at least 2 in. $\times$ 4 in., made of three parts, two of which are locked entire length, making a half-inch seam of three thicknesses. The third to be locked to first two parts by inseparable cleats every 18 inches. The two parts already mentioned to provide in themselves weather qualities and inseparable cleats for holding glass, thereby insuring stability by reducing to a minimum the parts and connections.

TOP-RAIL.—To be made in one piece, so formed as to afford ample weather qualities.

THE SILL.—To be made of one piece, formed so as to afford ample weather qualities and condensation sheds with outlets.

THE MIDDLE RAIL.—To be made of two pieces, forming an air-chamber with inseparable cleats, lock-jointed, and of length sufficient to extend in and through sides of frame, where the same is lapped four ways onto sides and riveted. The top of this rail receiving sash is made with a wash.

Connections of various parts of frame must, in all cases, be made by lapping prior to riveting.

SASH.—The plain frame, having top, bottom, and two sides, of air-chamber construction and made so that depth of sash is 2 inches, and width of same back or front or rabbet is 2 inches,

The same shall be lock-jointed throughout, shall have inseparable cleats, and all necessary weather qualities. The corners of this frame shall be double-locked. Each corner of frame shall be double-locked on front, back, and at sharp corners, so as to completely dispense with the need of solder and rivets. The sash shall be so made as to correspond with frame at points of meeting, and the hanging of same must be on horizontal pivots above the centre, to allow quick closing, as hereinafter arranged for, automatically.

Reinforce frame where pivots enter by riveting a strip of $\frac{1}{8}$-in. iron so bored as to allow a bearing for pivot.

The upright sash-rail must be made of one piece of galvanized iron or copper, with inseparable cleats and lock-jointed about an iron bar $\frac{1}{4}$ in.$\times 1\frac{1}{2}$ in., in a manner to afford an air-chamber of 1 inch square, and rabbets for holding glass, and the same lapped and riveted to frame and sash.

Mullion Windows.—Where an architect prepares clear opening for a mullion window, the metal frame must be reinforced at every point of division by structural iron, channels preferred. These divisions, that of necessity must be chambers of air-spaces, will afford ample room for channels. The channels must be built into window as made.

In General.—Flat surfaces that retain water must be avoided. The lock shall be a double-spiral spring brass lock, and shall be bolted to middle rail and sash.

The window shall be made with stationary lower sash, and upper sash swung on bearings in upper half of sash, and shall be so equipped with fusible link, rings, and rod, that the same will close and lock automatically under fire.

The rabbets against which the glass is set shall be for glass of a small to medium dimension, $\frac{1}{2}$ in. wide, and for a glass of more than medium dimensions, $\frac{3}{4}$ in. wide.

The inseparable cleat must be at least $1\frac{1}{2}$ in. in length, and must repeat at least every 12 inches.

Windows of more than ordinary width shall be reinforced by structural iron in cross-rail.

Caution must be had against using glass of unreasonable dimensions. For a window 4 ft.$\times$8 ft., arrange sashes for three lights each, or glass 15$\times$46. For a window 4 ft.$\times$6 ft., arrange sash for two lights each, or glass 22$\times$34. For a window 5 ft.$\times$8 ft., arrange sash for three lights each, or glass about 19$\times$46. My recommendations would be not to exceed in

width 18 inches, where height is 48 inches or more, and in no case to exceed 24 inches in width.

The following regarding shutters, etc., for protection against fire is taken from an address by John R. Freeman, Consulting Engineer, Providence, R. I., at the annual banquet of the National Board of Fire Underwriters, Delmonico's, New York, May 12, 1904, in response to the toast

"AN ENGINEER'S SUGGESTIONS TO FIRE UNDERWRITERS."

Concerning Fire-shutters.—A point which interested me exceedingly, in studying the Baltimore ruins, was to see whether thin wrought-iron or steel plate, such as is used for covering fire-shutters, had at any point been heated to a point where its power of resistance was seriously impaired. The ordinary underwriters' fire-shutter depends for its strength and its resistance upon its thin covering of very soft mild steel coated with tin. I examined thin sheet-steel lamp-shades, thin bands for pipe-coverings, tin boxes, filing-cases, and dozens of shutters themselves. In no place did I find any indication that metal of that quality had been so softened or had reached such a heat that it would be seriously impaired for the purpose of fire-shutters, and one of the great lessons that I brought away from the Baltimore fire was that our standard tin covering for the underwriters' shutter is all right, and that this covering material has sufficient power of resistance to withstand the fiercest heat of a great conflagration, but that we do need to find some better material than pine wood to fill it with. I also made careful examinations of copper in flashings, cornices, etc., to see if it had melted. In a few small spots in rare instances fusion had begun, but in general I found it had ample resistance to fusion, so that it can prudently be used for covering fire-shutters where something more ornamental or weatherproof than tinned plate is desired and expense is no bar.

The standard underwriter shutter of wood covered with tin did not give a very good account of itself in the Baltimore fire, and I think it can be said, without fear of serious contradiction, that the endurance of the ordinary underwriters' shutter of tin-clad wood is limited to not more than about half

an hour's endurance of a temperature of 1500 degrees, and that this limit is often passed in the heat of an ordinary conflagration, and that in many of the cases where single doors or shutters have shown up so well there has happened to be an incoming air-current that has helped to cool the shutter.

The limitations of the tin-clad wooden shutter were shown at one corner of the burned district in Baltimore. A large shirt factory whose windows were protected by wooden fire-shutters had a very close call. By heroic efforts with private pump and hose streams the employés saved the factory. I took particular interest in examining those shutters, and although this was not at the hottest part of the fire, I found, in parts of the shutter at the hottest exposure, that the pine wood was charred entirely through and all gone.

This matter of better shutters is one on which we should set some of our best talent at work in the experimental way. In your excellent laboratory in Chicago there is excellent apparatus for the needed tests. Although the present shutter and the present approved form of fire-door is all right nine-tenths of the time, and perhaps nineteen-twentieths of the time, it is not all that we need in a great conflagration.

I have said that buildings can be made fireproof against bad exposures. The possibility of making them so is found largely in the development of a superior thin form of fire-shutter, and in educating the architects and owners of buildings toward building a shape of window that is easily protected by the fire-shutter, and a neat window-jamb formed to receive this shutter when folded back *inside the window*.

Windows of suitable size for all ordinary office purpose can easily be so designed that they can be protected by fire-shutters, and that the shutters when open and folded back on the inside will not be obtrusive or unsightly. When a bad exposure fire comes the ruin of the sash and glazing can be paid for cheerfully if the contents of the building are saved.

I was very much interested in the efficiency of the plain steel-plate shutters on the inside of the windows in the Safe Deposit and Trust Company Building. These kept the fire out very successfully, notwithstanding that the large non-fire-proof building of the Baltimore *Sun*, which was entirely wrecked, and was one of the hottest parts of the entire conflagration, was only ten feet away. The damage was so imminent that the police ordered the men to leave the Safe Deposit

Building, and the heat melted the lead sash-weights within the cast-iron window-casings, destroyed the sash and glass, and chipped the brick walls, but the damage on the interior of the building was almost nothing. These steel-plate shutters were so set that they were free to expand, and they were free from ribs and of a form not likely to warp much, and they did in fact warp but little, and the casing and jamb were of such form that this warping of the shutter off its seat did not open a wide crack, and there was no combustible material near them on the inside to receive their radiant heat.

Capt. Sewell, if I understood his remarks aright, suggested a steel shutter stiffened by ribs.

Ribs are dangerous unless very carefully designed and attached, and as generally applied increase the liability to warp.

I happen to have been an eye-witness of the fire twenty or twenty-five years ago that gave to the tin-clad shutter its great start on the road to popularity. This fire was in the Pacific Mills, at Lawrence, Mass. In that case there was a tin-clad wooden fire-door, of what has since become standard construction, standing immediately beside a steel-plate shutter that was heavily ribbed on the edges. Apparently it was a fair comparative test for the two shutters. The ribbed-steel shutter warped away from its bearings two inches or three inches, as I now remember it, in a way that let the fire play freely around its edges, while the tin-clad wooden shutter remained in place without warping and was in good working order when the fire was over, the tin covering intact and the wood charred only about half an inch deep. These results were published far and wide, and this gave the first great impetus to tin-clad wooden shutters.

There have since been hundreds of demonstrations of the endurance of tin-clad shutters in fires, and I have taken advantage of many opportunities to examine carefully into the conditions under which they have been exposed. The result of these examinations has been to convince me that the endurance of the tin-clad shutter is limited; that its limit of endurance is often passed; that for severe cases we do need something better than the ordinary underwriters' tin-clad wooden shutter, and that we do need something very much better than the ribbed-steel shutter or the rolling jointed steel shutter.

At present the best we can do in any important case is to use two fire-shutters or fire-doors, one outside and another

inside; one will receive the brunt of the onslaught and perhaps in the course of half an hour or an hour warp or break down; the second, shielded behind the first, will stand up to its work until any ordinary fire is over.

It seems to me that the main reason why those steel shutters in Baltimore, at the building which I have just mentioned, performed so well was that they were free from ribs, and thus became heated more uniformly, with but very slight warping; that they happened to be so fastened to a frame that they were free to expand, and their seat happened to be of such a shape that, although the shutter did warp a little, this did not open much of a crack, and that there was no combustible material close to them on the inside.

The path of safety from exposure fires for office-buildings and the like lies in a window-casing formed so that we can attach to it a shutter of a form similar to the ordinary inside house-blind. Our ordinary business buildings have walls thick enough, so that by making the shutter in four folds, or leaves, two being hinged together, and these two in turn attached to the wall, making each fold in the shutter only about fifteen inches wide, the window will be wide enough for all practical purposes, and we can fold the shutter back within the window-jamb, very much as we do the inside blind.

To do that with the present ordinary tin-clad shutter would be almost impossible, because of the thickness of that form of shutter. It can be done with a steel-plate shutter without ribs and the radiation from the inside can be checked by some thin incombustible porous covering like asbestos board. If in our underwriters' laboratories, in our technical schools, and in our tours of survey we can direct attention to these views and urge the solution of the problem of how to make an efficient fire-shutter which shall only be three-quarters of an inch or an inch in thickness, I believe that before long the problem of protecting an office-building against exposure fires will be found solved.

It is entirely possible to design a window opening adapted to receive a safe shutter, so that it will be just as convenient for ordinary business purposes as the type now common. I think it probable that the best place for the shutters is *inside the glass*, sacrificing the glazed sash outside them in case of any great conflagration.

"WATER-CURTAINS" AND "WIRE-GLASS."—We hear a good

deal nowadays about "water-curtains," and I would like to say just a word on that, because I think there is a great deal of misapprehension about their efficiency. I would like to say a word about wire-glass also, because although in general excellent I think there is a great misapprehension as to what wire-glass can do.

I began experimenting with wire-glass very soon after it first came out, and I have used it in numerous instances, and it is a most excellent material in its way, but it has its limitations; it has the same limitations that a water-curtain has, and that is, that it does not stop the passage of radiant heat.

You all have noticed how, when you are travelling in a railway train, perhaps at sixty miles an hour, and they happen to be burning a pile of ties along the track, that although your face is directed towards your newspaper, you will feel the flash of heat passing through the car window and striking against your face as you go past that pile of burning ties. That simply illustrates the great ease and rapidity with which radiant heat passes through glass.

Now, radiant heat passes through glass with wire netting in it almost as easily as it does through any other glass, and the record made by wire-glass in a certain building in Baltimore, which is pointed to with so much pride, is, I think, simply due to the fact that it was at a place where nothing combustible was immediately behind it. If you have a stock of dry goods, or wooden ware, or baled cotton or hemp just inside a wire-glass window without shutters, and there is a hot fire across the street, these can probably be set on fire with much promptness by the radiant heat passing through the glass, and the subject should be thoroughly studied on a large scale in our underwriters' laboratories. For safety, there must be something which will stop the radiant heat, and that can only be in the form of a shutter, and, by virtue of stopping the heat, the shutter will become hot.

The case with the water-curtain is very much the same as with the glass. Water is diathermous, as physicists call it—that is, radiant heat passes through water very easily.

We must, I believe, set down these stories that have been told about the efficiency of water-curtains as being mainly fairy tales.

This supposed efficiency of the water-curtain is another

topic which I hope that some one of our underwriters' laboratories and some of our schools of applied science will take up and investigate with precision of measurement.

I have heard stories of the wonderful efficiency of the water-curtain, but I must beg to disbelieve them, largely on theoretical grounds as yet. It is a matter which can be tested very easily.

The window-sprinkler came in for a good deal of praise in certain quarters in Baltimore. I took particular pains to investigate that, because I wanted to find just how far they merited it, and I have no doubt they did some good, but they are not entitled to anything like the glory that is claimed for them. They will tell you a great deal about the remarkable work done by the window-sprinklers in the Toronto fire. Now, I sent a bright young engineer up there especially to investigate that question and to go into it in detail, and to take photographs of the individual windows and to get right down to the bed-rock facts, and, from the mass of evidence that he brings back, I do not doubt that they did some good; but *the inside ordinary automatic sprinkler near each of these windows did very much more good.*

In short, if you want to provide against an exposure fire, I believe that the only way to do it is,

First, by a wall either of brick or cement concrete.

Second, by properly designed window openings and window casings, and

Third, by good shutters in those windows.

In the absence of shutters, automatic sprinklers, supplemented by heroic efforts with hose streams on the inside, may sometimes save the day; with great expense for water damage, but where exposures are bad, a good shutter on a proper window should be the first care of architect and owner.

Fire Resisting Devices.—Of the many fire-retardant and fire-resistant devices with which the modern building is equipped much lies in the province of the superintendent. Perhaps in even larger measure than in the realm of materials does proper installation secure success.

The more important of these devices have been the subject of extensive investigations by the engineering bodies of the National Board of Fire Underwriters, and rules governing their manufacture and installation have been issued. Copies of these rules may be had gratis on application to the Na-

tional Board of Fire Underwriters, 32 Nassau Street, New York City.

Among the subjects covered are the following:

Rules and requirements for the installation of automatic electric fire-alarm systems and the construction of thermostat alarm circuit closers; the construction and installation and use of acetylene-gas machines, and for the storage of calcium carbide; the installation of auxiliary fire-alarm systems; the installation of automatic-sprinkler equipments; the construction and installation of stationary chemical fire-extinguishers; the manufacture of wired glass and the construction of frames for wired and prism glass used as a fire retardant; the construction, installation, and use of gasolene vapor gas lighting machines, lamps, and systems; for the installation of electric wiring and apparatus.

Each of these subjects is so thoroughly and concisely covered by the several rules just mentioned that their careful perusal by the superintendent will provide both information and incentive looking to the exercise of the most judicious care in all fire protection matters within his province.

Among the most important of the National Board's rules are those which deal with sprinkler systems and with the manufacture and installation of wire-glass and frames to contain the same.

The automatic sprinkler is a device for applying water for the extinguishment of fire, such water to be applied automatically at the right spot and in the least volume necessary for such extinguishment. This is accomplished by valves or sprinkler-heads which will open by the effect of heat from the fire they are intended to extinguish.

To secure the most efficient sprinkler service, the following general conditions should prevail:

1. Sprinklers to be so located that every portion of the building can be covered by water. This necessitates an open type of construction, free from concealed spaces where water cannot penetrate.

2. Sprinkler piping to be of ample size and provided with water at all times. Should danger of freezing exist, what is called the "dry-pipe system" should be used.

3. The general supply of water should be of ample pressure and volume, and the service be automatic in its action at all times.

Location of sprinkler-heads, sizes of piping, and general instructions for installation are fully set forth in the National Board's rules, to which the superintendent should refer.

As fire-escapes are one of the main features of building protection, the following is taken from the Philadelphia Building Law:

Formula Governing the Erection of Fire-escapes.—In accordance with the Act of Assembly approved June 3, 1885, and the Ordinance of Councils approved December 10, 1896, and supplemental thereto, the following formula will govern the matter of the design, construction, and erection of all fire-escapes hereafter required within the city of Philadelphia.

Platforms.—The platforms shall consist of iron balconies not less than four (4) feet in width, the length of the platform to be dependent upon the size of the building and the number of its occupants. The inspector of the district will designate the length of such platform, which shall extend in front of, and not less than nine (9) inches beyond, at least two windows, except in the case of a doorway leading from the floor level of the building to the floor level of the platform, in which case such doorway opening will suffice. Each platform shall be provided with a landing at the head and foot of each stairway of not less than twenty-four (24) inches, the stairway opening of the top platform to be no longer than sufficient to provide clear headway. The floors of balconies must be of wrought iron or steel, one and one-half ($1\frac{1}{2}$) inches by five-sixteenths ($\frac{5}{16}$) inch slats, not more than one and one-fourth ($1\frac{1}{4}$) inches apart, and be securely riveted to frame and brackets. Outside angle frame to be not less than two and one-fourth ($2\frac{1}{4}$) inch angle iron. If flooring is made of wire, same to be not less than No. 6 wire gauge, three-fourths ($\frac{3}{4}$) inch mesh, securely fastened to frame and brackets. All stair openings to be sufficient to provide clear headway. In all cases platforms must be designed, constructed, and erected to safely sustain in all their parts a safe load, at a ratio of four to one, of not less than eighty (80) pounds per square foot of surface.

Railings.—The outside top railing to extend around the entire length of the platform, and through the wall at each end, and to be properly secured by nuts and washers, or otherwise equally well braced and bolted. The top rail of the balcony must not be less than one (1) inch pipe iron, or material equally

as strong. The bottom rail must not be less than three-fourths ($\frac{3}{4}$) inch pipe iron, or material equally as strong, well leaded into the wall. The standards must be not less than one (1) inch pipe iron or material equally as strong, and must be securely connected with top and bottom rail and platform frame. Standards must also be securely braced by means of outside brackets at suitable intervals. Railings in all cases to extend around the stairway openings and be continuous down the stairway, the height of the railing to be not less than three (3) feet.

STAIRWAY.—Stairways must be designed, constructed, and erected to safely sustain in all their parts a safe load, at a ratio of four to one, of not less than one hundred (100) pounds per step, with the exception of the tread, which must safely sustain, at a ratio of four to one, a load of two hundred (200) pounds per tread. The treads to be not less than six (6) inches wide, and the rise not more than ten (10) inches. The stairs in all cases to be not less than twenty-four (24) inches wide, and the strings or horses to be not less than three (3) inch channels of iron or steel, or other shape equally as strong and to rest upon and be fastened to a bracket; said bracket to be fastened through the wall as otherwise provided for brackets. The strings or horses to be also securely fastened to the balcony at the top. The steps in all cases to be double riveted or bolted to the strings or horses.

BRACKETS.—Brackets must not be less than two and one-fourth ($2\frac{1}{4}$) inch angle iron, or material equally as strong, not more than three (3) feet apart, braced by means of not less than one (1) inch square, or one and one-fourth ($1\frac{1}{4}$) inch round iron, let into the wall at least four (4) inches, with shoulders on brace, and three (3) inch washer between shoulder and wall, and to extend down the wall four (4) feet from the top of the bracket, and out on the bracket angle three (3) feet from the wall. In all cases the bracket angle directly under the balcony must be secured to wall by means of bolts of suitable size passing through the wall, and four (4) inch washers. There must also be a bar of wrought iron or steel two (2) inches by three-eighths ($\frac{3}{8}$) inch, let into the wall four (4) inches edgewise, between the brackets, and riveted to the balcony for the floor to rest upon. Whenever the bottom balcony is supported by means of suspension-rods (riveted or bolted) to the balcony above, the brackets (of the above balcony) shall be increased

in size to meet the increase strain occasioned thereby. The bottom balcony to have a drop-ladder of same construction as the stairway, to be hinged and hung with a counter weight. Whenever the drop-ladder is upheld by means of a counter balance-weight suspended to a chain, such weight shall hang within the platform railing if practicable.

In all cases the bolts, rivets, and other material used shall be proportioned so as to develop the full strength of the members connected by them.

All the parts of such fire-escapes must receive not less than two coats of paint—one coat in the shop and one after erection.

Formula for Construction of Tower Fire-escape.—The said tower fire-escape shall be divided from the building by, and completely inclosed with, brick walls or such other fire-proof materials as shall be accepted by the Bureau of Building Inspection. The said walls to be built solidly from the foundation to and at least 36 inches above the roof.

The roof of said tower shall be built of hard, incombustible materials.

The stairs of said tower may be iron or wood; but in all cases there must be provided stone or iron thresholds, iron frames, or wood frames covered with metal, and iron doors, or wood doors covered with tin. The rise of said stairs shall not be more than eight (8) inches and the tread not less than nine (9) inches. The entrance to said tower shall be by means of an outside balcony or an incombustible vestibule, of which one side shall be entirely open and extend from the top of floor to under side of ceiling and the full width of the tower, the said open side to face a street or such open space as provides for exit of said tower.

There shall be a brick wall, or other wall of hard, incombustible material separating the tower from the vestibule. The opening into tower from said vestibule to be not over seven (7) feet in height. The floor, ceiling, and sides of said vestibule to be of hard, incombustible material.

The rails inclosing the side facing the open space or street, to be not over four (4) feet high and not less than three (3) feet, may be open or inclosed.

The entrance to the tower from the building shall be through the vestibule.

Towers that have not the fire-proof vestibule shall have outside balconies; floors of balconies to be solid, and built

of hard, incombustible material, and be of sufficient strength to carry the imposed weights.

The rails around said balconies shall be not over four (4) feet in height nor less than three (3) feet, and may be inclosed or open.

PART IV.

LATHING AND PLASTERING. CARPENTRY; TIMBER. PLUMBING. TIN AND SHEET METAL WORK. PAINTING, GLAZING, AND PAPER-HANGING. IRONWORK. ELECTRIC WIRING, ETC. HEATING.

Lathing and Plastering.—The duties of the superintendent during this branch of the work will be first to see that the laths, when wooden laths are used, are sound, straight-grained, and free from sap, loose knots, or oil.

As the laths are put on he should see that they are nailed solid and given the proper space between; they should be spaced about $\frac{3}{8}$ inch apart for ordinary lime mortar and about $\frac{1}{4}$ inch apart when any of the hard or patent plasters are used. The laths should have one nail to every bearing and have two nails to each end. The perpendicular joints in the laths should be broken about every six lath. No laths should be set vertical to fill out any corner or any other place. Where laths cross a bearing over two inches wide a lath or strip should be put under the laths so the plaster will have a chance to key.

Laths over door or other openings should have as few vertical joints as possible so as to prevent cracks; if possible the laths should extend across the opening.

1000 laths $1\frac{5}{8}$ inches wide will cover about 570 square feet.

1000 laths $1\frac{1}{2}$ inches wide will cover about 620 square feet.

1000 laths require about 5 pounds of lath nails, 6 nails to a lath.

Metal or Wire Lathing.—Where metal or wire lathing is used it must be stretched tight and securely fastened. If it is put on wooden joists or studs it should be fastened with staples, and if fastened to metal furring or beams should be fastened with galvanized or coated wire. All metal lathing should be coated to prevent rust; it is usually prepared in this way by the manufacturers. In all angles where wood or terra-cotta partitions join the main wall of the building there should be a strip of the metal lath bent in the angle and extending out on each side about six inches and securely fastened; this will prevent any cracks in the angles after the plastering is done.

Corner Beads.—Metal corner beads should be used on all external angles, and care must be taken in setting them to get them straight and fastened solid.

Plastering.—Lime for making mortar for plastering should be of the very best quality and free from all dirt. It should slake readily so there will be no unslaked particles of lime in the mortar to slake after it is put on the wall. If this happens the small pieces of lime swelling and slaking will cause small pieces of the plaster to fall off, leaving "pits" or holes. The lime should be slaked at least a week before being put on the wall.

Sand.—The sand should be sharp and angular, free from any dirt or oil or anything to stain the plaster. When sea sand is used it must be thoroughly washed with fresh water so as to remove all salt.

Hair and Fibre.—These are used in the mortar to form a bond and bind the sheet of mortar together. Cattle hair is generally used, but of late years jute and several fibre products have been used satisfactorily to a great extent.

Plaster of Paris.—Plaster of Paris is prepared by grinding and heating natural gypsum in a furnace so as to drive off its water of crystallization. Plaster of Paris owes its value to the property it possesses of absorbing water and passing into the water-soaked condition, in doing which it sets into a hard mass. This setting takes place quickly, but sufficient time elapses between mixing it with water and setting to permit it to be run into moulds or for coating surfaces, and to gauge the skim or finish coat and for running cornices, centre-pieces, and other ornamental work. Plaster of Paris should be kept in a dry place, as it readily absorbs moisture.

The superintendent should see that the mortar is made up at

least a week before it will be required for use. Ordinarily the hair is mixed with the mortar when it is made up, but on first-class work it should be added when the mortar is mixed for use.

When the hair is added to the mortar when the lime is first slaked there is danger of the hot lime burning the hair and causing it to rot.

Before the mortar is put on the superintendent should examine all grounds to see that they are straight and solid, also see that all gas and electric outlets are in their proper places, and that every possible provision has been made for securing the wood or other finish in place. All walls should be dusted off and wet before any mortar is put on. The superintendent should watch and see that the plasterers use sufficient force in spreading the first coat of mortar to force it through the lathing and key in all spaces. The space back of all wainscot or base should be plastered flush with the face of the grounds, so the wood will lay solid against the plaster.

Cornices or any ornamental work should be run and put in place before the finish or skim coat of plaster.

In putting on the skim coat the superintendent must see that it is given sufficient trowelling to bring it to a smooth glossy surface. By looking along the finished walls where the light strikes them he can tell if they have a good finish; there should be no trowel- or brush-marks show on the finished surface.

Patent Plasters.—There are a number of hard or patent plasters on the market and sold under various names, as Adamant, King's Windsor, Rock Wall, Granite, Elastic Pulp, Ideal, Elyria Wood, Kallolite, Imperial Wall, etc.

The composition of the various plasters is pretty much the same, the hardness being based on the plaster of Paris or gypsum used in their manufacture. These plasters give good satisfaction and make a hard durable job of plastering. For quick work or for use in cold weather they are preferable to lime plaster, as they will set and harden much quicker.

When any of the hard finishes are used the plasterer will generally try to work lime putty in along with it to make it work smoother and easier. This may be permitted to the extent of about 15 per cent lime putty, but no more, and when this permission is granted the superintendent will have to watch to see that no more is used.

The covering capacity of the different patent plasters varies from 90 to 150 yards per ton of plaster.

OUTSIDE STUCCO-WORK.—This is the name usually given to exterior plastering, and is generally done with cement mortar. Care should be taken to keep any outside work from freezing, or from being dried too fast with the heat; it should be shaded to protect it from the sun, and wetting it two or three times a day for several days will improve it.

SCAGLIOLA.—This is a composition made to imitate marble. It is composed of plaster of Paris or Keene's cement mixed with glue or gelatine and the various colors are added to obtain the desired imitation. This work when properly done will take a good polish and makes a good imitation of marble.

CORNICES AND MOULDINGS.—Cornices, mouldings, etc., are usually run with a mould made of sheet iron and cut the reverse contour of the mouldings to be run. Strips of wood are tacked around the walls and ceiling to form a guide to run the mould along. These moulds are usually made to set at right angles to the mouldings, thus leaving a space the width of the moulding or cornice at all angles which have to be worked out by hand. If the mould is made to set at an angle of 45°, or a true mitre with the moulding and the mould made to correspond with the profile of the mouldings on this angle, then the mould can be run in close to all angles. Fig. 210 shows how this mould is made and used.

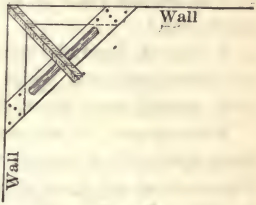


FIG. 210.

PLASTERING DATA.—1 barrel of lime will make about $2\frac{3}{4}$ barrels of paste.

1 bushel of hair weighs about 15 pounds.

1 barrel of lime, 18 cubic feet of sand, and 22 pounds of hair will brown coat about 40 yards on wooden lath with $\frac{7}{8}$-inch grounds, or about 32 yards on brick or terra-cotta walls with $\frac{5}{8}$-inch grounds, or about 30 yards on wire or metal lath.

1 barrel of lime, 1 barrel of plaster of Paris, 1 barrel white sand will skim coat about 140 square yards.

First coat mortar = 1 barrel lime, 18 cubic feet sand, $1\frac{1}{2}$ bushels hair.

Second coat mortar = 1 barrel lime, $21\frac{1}{2}$ cubic feet sand, $\frac{3}{4}$ bushel hair.

Lafarge Cement.—Lafarge cement is much used for outside stucco-work. It should be mixed as follows:

First coat, 1 part cement, 3 parts sand, 25 per cent lime paste, and sufficient hair.

Second coat, 1 part cement 2 parts sand, 10 per cent lime paste. 1 barrel of cement and 3 of sand will cover about 34 square yards ⅜ inch thick.

1 barrel of cement and 2 of sand will cover about 25 square yards ⅜ inch thick.

Keene's Cement.—This cement, or plaster, is made by recalcining plaster of Paris after soaking it in a solution of alum; it is used for wainscot, base, caps, etc., and also for hard finish.

The first coat is composed of 1 part cement, 1 part lime paste, and 3 parts sand.

The second coat of 1 part cement, 1 part lime paste, and 4 parts sand.

1 ton of Keene's cement will first coat about 475 yards, or brown coat and white hard finish about 300 yards, or first and second coat about 350 yards.

Whitewash.—Common whitewash is made by slaking fresh lime and adding enough water to make a thin paste; by using 2 pounds of sulphate of zinc and 1 pound of salt to each half bushel of lime the whitewash will be much harder and not crack. A half pint of linseed-oil to each gallon of whitewash will make it more durable for outside work. To color add to each bushel of lime 4 to 6 pounds of ochre for cream color; 6 to 8 pound-amber, 2 pounds Indian red, and 2 pounds of lampblack for fawn color; 6 to 8 pounds raw umber and 3 or 4 pounds lamps black for buff or stone color.

Carpentry.—In superintending this branch of work, the superintendent, in addition to examining the materials used, will be required to see that all work is fitted together and secured in a proper manner.

In fire-proof structures, among the first work of the carpenter will be the setting of the window-frames, laying floor strips, etc.

Before being set the window-frames should be examined to see that they conform to the detail drawings, that the pulleys and pockets are put in as desired, and that partitions are provided in the boxes to separate the weights. Care should be taken in setting the frames to get them plumb, and to show theproper reveal on the outside jamb; then they should be se-

curely fastened to the anchors or whatever means that have been provided for fastening them. As soon as the frames are set the sills should be covered to protect them from any damage.

Floor Strips.—The setting of the floor strips will require close attention to be got straight and level, and the superintendent should see that this is done or a bad floor will be the result. Where there is to be a diagonal underfloor laid there should be a floor strip around all sides of the room to catch the ends of the diagonal flooring. After the concrete filling is put in place all the floor strips should be examined with a straight-edge, and any not straight or level should be taken out and reset.

In putting down the floor strips, they should be run so that when the finished floor is laid it will run lengthwise of the room.

Wherever an underfloor is used it should be laid diagonally, as the top floor can then be laid across the floor strips, and also across the joints of the underfloor. If the underfloor is laid in the same direction as the top floor it will cause much trouble in laying the top floor, as the underfloor will usually cup up at the joints enough to make the top floor irregular, but if the top flooring crosses the underfloor this trouble will be avoided.

In terra-cotta and other fire-proof partitions it is customary to set a rough-wood frame in the opening, and build up to it. Care must be taken to have these frames set plumb and securely fastened top and bottom, and as the tile is built up against them, to fasten the tile to them with metal clips, or nails driven through the tile. As the partitions are built, provisions must be made for nailing or fastening the wood finish. (See page 303.)

Joists.—In framing wood joist for a building, they should be given a "camber" or crown of about ½ inch in 20 feet, and the end should be cut on a bevel of about 4 inches, so that in case of fire the joist can drop out of the wall and do no damage. In levelling up joists no wood should be used, but the joist blocked where necessary with slate or flat pieces of iron. Wood joist in brick or stone walls should have the ends cut on a bevel, so that in case of fire, the joist can drop out without pulling down the wall.

In setting joists the superintendent should see that none are set less than 8 inches from the inside of any flue, and 4 inches from any chimney or hot-air pipe; he should watch as the

joist are framed together and see that all joints are tight and have good bearings.

Bridging.—All joists should be bridged as the specifications may call for. The bridging should be heavy enough so that two tenpenny nails can be used in each end without splitting the bridging. It should be cut and put in place by nailing the top end only, leaving the bottom end to be nailed after the floor is laid; in this way the flooring draws the joists to a straight line and the bridging braces and holds them there. The nails should be started in the lower end before the bridging is put in place; then all that remains to be done is to drive them home after the floor is laid.

Grounds.—This is one of the most particular parts of the carpenter-work, and one that is most often slighted. If the grounds are not put up solid and straight, then the plastering will be crooked and the wood finish will not fit the walls tight. The superintendent should pay special attention and see that all the grounds are put up in the best possible manner; he should take a straight-edge and try them, and if he finds any not straight, have them made so at once.

Partitions.—All stud-partitions should be bridged at half-height; the studs should be brought to a line by tacking a straight piece of 2×4 or 2×6 along them as shown at *B*, Fig. 211. One of the best methods of bridging is shown in Fig. 211, called "herring-bone" bridging; material of the same dimensions as the studs is used, and being set on an angle, as shown, gives a good chance for nailing the ends of the bridging and making the partition solid.

Fig. 212 shows another good method of bridging, by running the bridging horizontally, but setting it diagonally across the stud, as shown at *A*, each alternate piece of bridging being set at opposite angles. Bridging set in this manner gives the plastering a chance to key, and there will be no "dead" plaster.

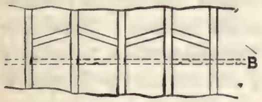


Fig. 211.

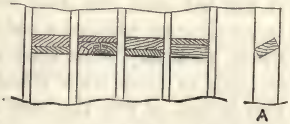


Fig. 212.

Door Openings.—All door openings in partitions which carry any weight should be trussed as shown in Fig. 213, and

for bracing it is well to continue the brace to the floor, as shown. In stud partitions a block should be placed at the sides of the door openings to catch and nail the end of the base to, as shown at *A*, Fig. 213.

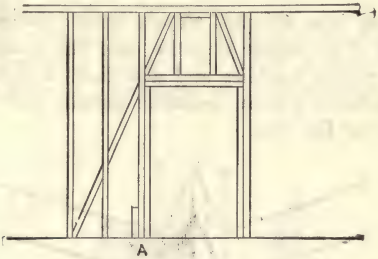


FIG. 213.

ANGLES.—Care must be taken to make all angles solid, and in no case should one be permitted to set the partition-studs so that laths can be run from one room to another. Fig. 214

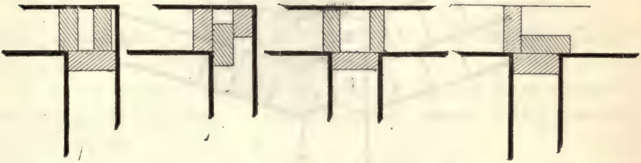


FIG. 214.

shows several methods of setting studs at angles. All studs for partitions should be sized to a width, and all caps and plates sized to a width and thickness; this saves much time and trouble and makes straight work.

SHINGLING.—In laying shingles the essential points are that the shingles be not too wide, that each shingle receives two nails, that they are not laid too much to the weather, that the joints are well broken, that the shingles have a good lap and are fitted close along any ridges, hips, etc. Shingles should not be over 7 inches wide to make a good roof, and any over this width should be split in two. Each shingle should receive two nails, regardless of its width. Shingles should not be laid more than 5 inches to the weather, and 4½ inches makes a better roof. In laying shingles the joints should be broken and the shingles lapped enough, so that there is

no danger of the water following under the shingle to the joint in the course below; care should be taken to break joints with the last two courses laid so that, in case a shingle should split under a joint, the split will not come over a joint in the course below.

In shingling hips the full shingle should be carried out to the hip, and if no saddle is to be used the courses should be lapped and woven together and also flashed so as to make a water-tight job, or a more desirable method called the Boston hip is shown by Fig. 215.

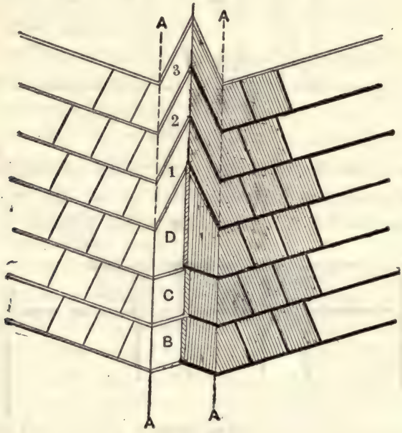


FIG. 215.

Gauged shingles or shingles of a uniform width should be selected to shingle the hip and two lines drawn on the sheathing parallel to the hip, as at AA, AA. The roof-shingles should be carried up to these lines in steps as shown by 1, 2, 3, after which the hip should be shingled, as shown by B, C, D, working the shingles so they lap alternately as shown. This makes a very neat and water-tight hip.

When valleys are to be shingled close and flashed, the superintendent must see that flashings of a large enough size are used and that no nails are driven where they will be liable to cause a leak.

In open valleys, in order to keep both sides of the shingles straight, a good scheme is to lay a studding of the desired width in the valley and fit the shingles up to it on both sides.

The superintendent should see that the shinglers do not drive nails through the roof in building their scaffold. This is often done and the nail-holes plugged up as they take down the scaffold; but it should never be permitted, for the plugs will rot or dry out and cause a leak.

In shingling up the corners of a building or the hips of a roof, the shingles should be lapped, as shown in Fig. 216, as this will show the edge of the shingle on both sides of the corner,

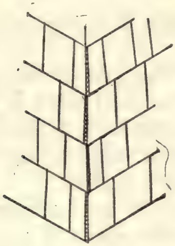


Fig. 216.

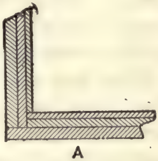


Fig. 217.

or hip, alternately. *A*, Fig. 217, shows how the shingles should be lapped two courses at a time.

If the courses of shingles are simply lapped time about it will bring all the edges of the shingles to show on the one side of the corner.

Flashing should be used up the sides of all frames and across the top, or any place where the water is liable to penetrate. Shingles should always be laid with galvanized nails.

Four pounds of 4d common or three pounds of 3d common wire nails will put on 1000 shingles.

The following table shows the number of shingles required to a square and the surface 1000 shingles will cover:

Exposure to the Weather in Inches.	Number of Square Feet of Roof Covered by One Thousand Shingles.		Number of Shingles Required for One Hundred Square Feet of Roof.	
	Four Inches Wide.	Six Inches Wide.	Four Inches Wide.	Six Inches Wide.
4	111	167	900	600
5	139	208	720	480
6	167	250	600	400
7	194	291	514	343
8	222	333	450	300

The average width of shingles is 4 inches; thus 1000 shingles is the equivalent of 1000 shingles 4 inches wide. This is usually four bunches, as each bunch contains 250 shingles, although on the Pacific Coast the redwood shingles are put up 200 to a bunch and four bunches are sold for 1000 shingles, while in reality they contain but 800. This same rule is used by the shinglers in that section of the country: they charge so much a thousand for laying the shingles, but call four bunches 1000.

To approximate the number of squares in a roof, see page 555.

SHEATHING.—When the sheathing of the roof is being put on the superintendent should see that a good joint is made along the line of the hips and valleys, so the lining of the valley will lay solid, and that there will be solid wood at the angle of the hip to hold the nails of the shingles or slate.

FLAG-POLES.—Masts or flag-poles should be made with a small swell to them, as described for the entasis of columns, page 574.

PITCH OF STAIRS.—In putting up horses for stairs and getting them out the tread should be made to pitch about $\frac{1}{8}$ inch in its width, as this makes a much easier stair than if the treads were perfectly level.

SASH AND DOORS.—Great care must be taken in fitting sash and doors, and also in hanging them; they should have just enough play to work without binding. One of the main troubles with sash is found in the thickness of the sash and meeting-rail, the sash often being made too thick for the runs in the frame. When the meeting-rails are too thick they will strike as the bottom sash is closed and pull the top sash down from the top; then when the bottom sash is raised there will be too much play between the sash and the parting bead, as shown at *B*, Fig. 218, and the sash will rattle. *A*, Fig. 218, shows how the meeting-rails should come together. Care also must be taken in hanging the sash to get the proper weights so the sash will be evenly balanced.

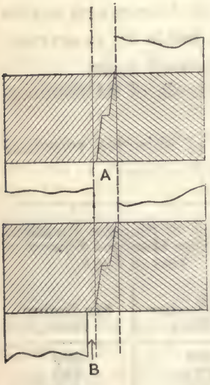


FIG. 218.

Panel-mouldings.—The superintendent should examine all doors and panel-work and see how the mouldings are nailed or fastened. The moulding should be nailed to the rail or stile as shown at *A*, Fig. 219, and not to the panel. If the moulding is fastened to the panel and the panel shrinks, as it generally does, it will make an open joint as shown at *B*.

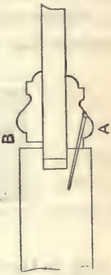


Fig. 219.

In nailing up finish or any interior work, the nails should be concealed as much as possible; this can be done by nailing in members of the mouldings which will be covered, or if the moulding is all exposed, by nailing in the quirks of the moulding where it will not be noticed after being puttied up; in quartered oak, chestnut, ash, etc., if the nail is driven in one of the pores of the wood and puttied neatly it will not be noticeable.

Securing Interior Wood Trim.—During the entire construction of a building the superintendent must see that proper provisions are made as the work progresses for nailing or fastening the wood finish or trim. Until recent days it has been customary to build wood blocks in the wall and nail the trim to these blocks. Wood blocks in some cases do not give entire satisfaction, as they are liable to shrink and come loose, and this will usually happen unless they are built in properly.

Of late some architects go so far as to specify that no wood blocks or plugs shall be used to secure the inside trim. Still there are some places where, if built in properly, a wood block will give better satisfaction than anything else for nailing and securing the trim. For base moulding, chair-rail, picture mould, etc., a wood block, if cut dovetail shape as shown by Fig. 220 and built solid in the wall will give good satisfaction and can never come loose, or take a wood block and drive nails in both sides, leaving the nails project out about ¼ inch and build this in the wall so the projecting nails are bedded in the mortar joint, it will always remain solid and secure.


Fig. 220.

If it is not desired to use wood blocks exposed, a terra-cotta block filled with wood and built in the wall will answer quite as well provided nails long enough are used so as to reach into the wood.

All door openings in terra-cotta walls usually have a rough stud frame, as shown at *A*, Fig. 221, and the tile should be built up to this frame and each course nailed or anchored to the stud.

Wherever there is to be any nailing in the terra-cotta the author has derived the best satisfaction by inserting a wood

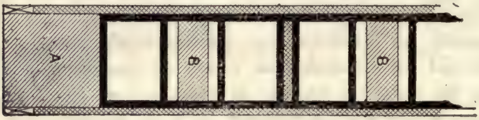


Fig. 221.

block in the tile as shown at *B*, Fig. 221, and then nailing through the tile into the block. Terra-cotta is supposed to hold a nail, but will not give satisfaction for nailing trim to; the jar of the hammer in setting the nail will nearly always jar the nail loose.

Fig. 222 shows a good method of fastening window-frames and securing the trim; the bolts as shown are built in as the

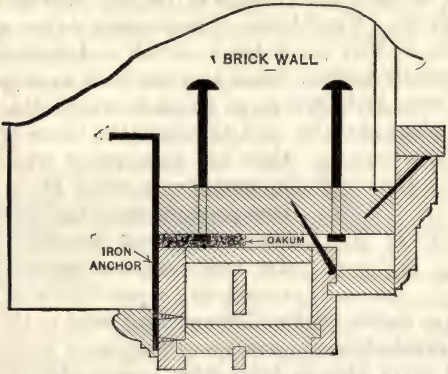


Fig. 222.

walls are built, and a 2-inch nailing-piece is bolted fast as shown, keeping one edge out to form a plaster ground. The frame can be set and anchored as shown, and the trim nailed to the nailing-piece before the back strip is put on.

The space around the frame should always be well calked with oakum or mineral wool.

Door-frames and trim in brick openings can be secured in a similar manner.

Metal nailing-plugs are used to some extent for securing finish or trim, but nothing gives as good satisfaction as wood securely anchored. In some cases expansion-bolts can be used with good satisfaction where there is nothing to nail to.

Figs. 223 and 224 show a method the author has used for fastening up wainscotting to brick walls, the bolts, as shown, being built in as the walls were built; the blocking or core piece, as shown, is bolted fast to the wall as the wainscot is put up and bolted fast. The cap and base can then be nailed securely to the wainscot and blocking.

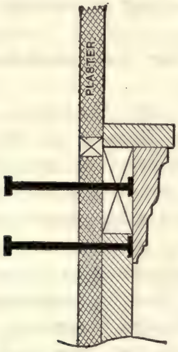


FIG. 223.

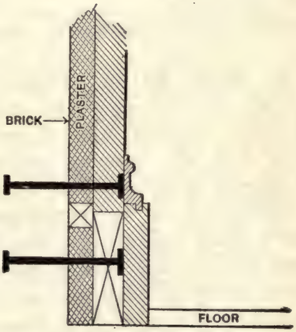


FIG. 224.

In tile partitions, in place of a bolt being built in the wall a toggle bolt can be used.

HARDWARE.—All hardware should be fitted in place before any painting or varnishing is done, and when this is done the superintendent should have it left in place long enough for him to examine it and see that all pieces work easily. After examining them all he should have all hardware taken off and put on final at the completion of the painting.

HANDS OF DOORS.—The hand of a door is determined from the outside of a building, room, or closet. Door No. 1 in Fig. 225 is a right-hand door because it opens to the right as you enter the room, and No. 2 is a left-hand door, as it opens to the left as you enter.

If the doors open to the outside, as shown in Fig. 226, door

No. 1 will be a right-hand reverse bevel, because it opens to the right, and No. 2 will be a left-hand reverse bevel, as it opens to the left, but the bevel for locks for these doors will

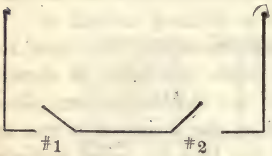


Fig. 225.

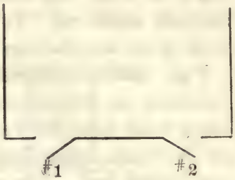


Fig. 226.

be just the reverse of those for doors hung or opening on the inside of the room.

Regarding wood beams, etc., the New York Building Code says:

Sec. 59. Wood Beams, Girders, and Columns. — *Wood Beams.*—All wood beams and other timbers in the party wall of every building built of stone, brick, or iron shall be separated from the beam or timber entering in the opposite side of the wall by at least four inches of solid masonwork. No wood floor-beams or wood roof-beams used in any building hereafter erected shall be of a less thickness than three inches. All wood trimmer and header beams shall be proportioned to carry with safety the loads they are intended to sustain. Every wood header or trimmer more than four feet long used in any building shall be hung in stirrup-irons of suitable thickness for the size of the timbers. Every wood beam, except header and tail beams, shall rest at one end four inches in the wall, or upon a girder as authorized by this Code. The ends of all wood floor- and roof-beams, where they rest on brick walls, shall be cut to a bevel of three inches on their depth. In no case shall either end of a floor- or roof-beam be supported on stud partitions, except in frame buildings. All wood floor- and wood roof-beams shall be properly bridged with cross-bridging, and the distance between bridging or between bridging and walls shall not exceed eight feet. All wood beams shall be trimmed away from all flues and chimneys, whether the same be a smoke, air, or any other flue or chimney. The trimmer beam shall be not less than eight inches from the inside face of a flue and four inches from the outside of a chimney-breast, and the header beam not less than two inches from the

outside face of the brick or stone work of the same, except that for the smoke-flues of boilers and furnaces where the brickwork is required to be eight inches in thickness, the trimmer beam shall be not less than twelve inches from the inside of the flue. The header beam, carrying the tail beams of a floor, and supporting the trimmer arch in front of a fireplace, shall be not less than twenty inches from the chimney-breast. The safe carrying capacity of wood beams for uniformly distributed loads shall be determined by multiplying the area in square inches by its depth in inches and dividing this product by the span of the beam in feet. This result is to be multiplied by seventy for hemlock, ninety for spruce and white pine, one hundred and twenty for oak, and by one hundred and forty for yellow pine. The safe carrying capacity of short-span timber beams shall be determined by their resistance to shear in accordance with the unit stresses fixed by Section 139 of this Code.

Sec. 60. *Anchors and Straps for Wood Beams and Girders.*—Each tier of beams shall be anchored to the side, front, rear, or party walls at intervals of not more than six feet apart with good, strong, wrought-iron anchors of not less than one and a half inches by three-eighths of an inch in size, well fastened to the side of the beams by two or more nails made of wrought iron at least one-fourth of an inch in diameter. Where the beams are supported by girders, the girders shall be anchored to the walls and fastened to each other by suitable iron straps. The ends of wood beams resting upon girders shall be butted together end to end and strapped by wrought-iron straps of the same size and distance apart, and in the same beam as the wall anchors, and shall be fastened in the same manner as said wall anchors.

Or they may lap each other at least twelve inches and be well spiked or bolted together where lapped.

Each tier of beams front and rear, opposite each pier, shall have hardwood anchor strips dovetailed into the beams diagonally, which strips shall cover at least four beams and be one inch thick and four inches wide, but no such anchor strips shall be let in within four feet of the centre line of the beams; or wood strips may be nailed on the top of the beams and kept in place until the floors are being laid. Every pier and wall, front or rear, shall be well anchored to the beams of each story with the same size anchors as are required for side walls, which anchors shall hook over the fourth beam.

Sec. 61. *Wood Columns and Plates.*—All timber columns shall be squared at the ends perpendicular to their axes.

To prevent the unit stresses from exceeding those fixed in this Code, timber or iron cap and base plates shall be provided.

Additional iron cheek plates shall be placed between the cap and base plates and bolted to the girders when required to transmit the loads with safety.

Sec. 62. Timber for Trusses.—When compression members of trusses are of timber they shall be strained in the direction of the fibre only. When timber is strained in tension, it shall be strained in the direction of the fibre only. The working stress in timber struts of pin-connected trusses shall not exceed seventy-five per cent of the working stresses established in section 139, this Code.

Sec. 63. Bolts and Washers for Timber-work.—All bolts used in connection with timber and wood-beam work shall be provided with washers of such proportions as will reduce the compression on the wood at the face of the washer to that allowed in Section 139, this Code, supposing the bolt to be strained to its limit.

Nails.—*Functions and Requirements.*—Nails are used to fasten pieces of wood superposed or adjacent to each other. They are driven perpendicularly to the materials when they are superposed and obliquely when adjacent. In the former case they draw directly in line of the axis of the nail, and in the latter, obliquely to its axis; in this case the rigidity or transverse strength of the nail plays an important part.

In all cases the adhesive resistance of a nail is nearly in ratio to the area of surface of the nail subjected to compression of the wood fibre, into which it is imbedded. It is therefore requisite that the greater portion of the nail be imbedded in the piece to which another is fastened; but in no instance is it necessary that it should penetrate through it.

Adhesive Resistance.—This property in a nail is secondary to none, and must always be supplemented with the proper area of head to increase the crushing strength of wood fibre, in order that a nail may fulfill its primary function of holding pieces together by compression.

It has been found in practice that the cut nail is harder to drive in than the wire nail, on account of the blunt point and tapering sides. While it has more adhesive resistance than a smooth wire nail of the same length, this is due directly to the

fact that two of its sides are tapering, or wedging, and that it has nearly twice the area of compression; but the slightest withdrawal of the nail releases the wedge, which immediately reduces the area of compression and lowers its adhesive resistance about 40 per cent.

This is not so with the wire nail, because the area of compression only varies as the distance the nail is imbedded, and its adhesive resistance is nearly in ratio to this area.

From what has been stated it is readily seen that the greatest area of compression and adhesive resistance in a cut nail is towards the head of the nail, whereas it should be at the point, while in the wire nail it varies only as the units of its length; therefore the excess of metal used and the very form of the cut nail is primarily wrong, as proved by modern practice, and is contrary to the very sense of its purpose, while the wire nail fulfils the requirements of a perfect nail.

Herein follow tables showing comparative tests of smooth steel wire nails, steel cut nails, and coated steel wire nails, with reference to their area of compression and adhesive resistance to pull.

TESTS SHOWING ADHESIVE RESISTANCE FOR EACH ONE-HALF INCH UNIT OF LENGTH OF NAIL IMBEDDED INTO WHITE PINE.

Kind of Nail.	Commercial Gauge.	Diameter in Inches.	Adhesive Resistance in Pounds for Each ½-inch Unit.			
			2 Ins., Lbs.	1½ Ins., Lbs.	1 In., Lbs.	½ In., Lbs.
8d common smooth wire	10¼	.135	210	170	140	90
10d common smooth wire	9	.148	200	150	110	80
20d common smooth wire	6	.192	220	130	110	80
8d common coated wire nail	11	.120	370	280	220	120
10d common coated wire nail	10	.135	400	330	250	150
	Dimensions.					
8d common cut steel	10½×9		260	90	40	0
10d common cut steel	10½×5½		320	140	60	0
20d common cut steel	7 ×4		280	90	40	0

Remarks.—The resistance here given was recorded on the machine gauge, the nail being driven into the wood 2 inches deep, then each reading of the gauge was taken successively as the nail was withdrawn to the measurements given.

A CUT NAIL LOSES FORTY PER CENT OF ITS ADHESIVE RESISTANCE THE MOMENT IT HAS BEEN SLIGHTLY WITHDRAWN.

Kind of Nail.	Commercial Gauge.	Distance Imbedded, Inches.	Resistance to Initial Pull, Lbs.	Resistance Second Pull, Lbs.	Resistance Loss after First Pull.	Per Cent Loss.
8d cut common	10½	1½	260	160	100	40
12d " "	9	2	390	220	170	43

Remarks.—The first pull extracted the nail about $\frac{3}{32}$ inch.

ORDNANCE DEPARTMENT, U. S. A.

Reports of mechanical tests made with the United States Testing Machine at Watertown Arsenal, Watertown, Mass., June 30, 1902, and August 5 and 16, 1902, for J. C. Pearson Company.

(Nails driven perpendicular to the grain of the wood. All nails driven in the same stick.)

Test Number.	Description of Nail.			Length Driven, Inches.	Adhesive Resistance, Total Lbs.	Average, Lbs.
	Size and Name.	Diameter, Inches.	Total Length, Inches.			
11.989	10d common smooth .	.145	2.99	2.50	136	167
	10d " " .	.145	2.99	2.50	144	
	10d " " .	.145	2.99	2.50	220	
12.058	10d coated..........	.117	3.00	2.50	414	418
	10d "	.117	3.00	2.50	406	
	10d "...........	.117	3.00	2.50	435	
11.991	9d common smooth .	.132	2.83	2.25	226	182
	9d " " .	.132	2.83	2.25	125	
	9d " " .	.132	2.83	2.25	196	
11.992	9d coated..........	.114	2.68	2.25	345	327
	9d "	.114	2.68	2.25	318	
	9d "	.114	2.68	2.25	317	
11.993	8d common smooth .	.132	2.52	2.00	146	189
	8d " " .	.132	2.52	2.00	228	
	8d " " .	.132	2.52	2.00	192	
12.044	8d coated..........	.112	2.39	2.00	322	316
	8d "	.112	2.39	2.00	318	
	8d "	.112	2.39	2.00	309	
11.998	6d common smooth .	.097	2.05	1.625	100	106
	6d " " .	.097	2.05	1.625	112	
	6d " " .	.097	2.05	1.625	105	
12.059	6d coated..........	.092	1.94	1.625	214	226
	6d "	.092	1.94	1.625	218	
	6d "	.092	1.94	1.625	247	

The coated nails used in making the above tests were those manufactured by J. C. Pearson Company, Boston.

The various kinds of nails derive their names from their shape, material from which they are made, or from the use for which they are intended.

The term penny, as applied to nails, is derived from pound. It originally meant so many pounds to the thousand. Three-penny nails would mean three pounds to the thousand nails; eight-penny, eight pounds to the thousand nails, etc. Now the term penny is used only to refer to the length of the nail.

3 lbs. 8d nails will lay one square flooring,
2 " 8d " " " " " sheathing.
2 " 8d " " " " " siding.

For quantity of nails required see Lathing, Shingling, and Slating.

SPIKES, NAILS, AND TACKS.

Standard Steel Wire Nails.						Steel Wire Spikes.			Common Iron Nails.		
		Common.		Finishing.							
Sizes.	Length, Inches.	Diameter, Inches.	Number per Lb.	Diameter, Inches.	Number per Lb.	Length, Inches.	Diameter, Inches.	Number per Lb.	Sizes.	Length, Inches.	Number per Lb.
2d	1	0524	1060	.0453	1558	3	.1620	41	2d	1	800
3d	1¼	.0588	640	.0508	913	3½	.1819	30	3d	1¼	400
4d	1½	.0720	380	.0508	761	4	.2043	23	4d	1½	300
5d	1¾	.0764	275	.0571	500	4½	.2294	17	5d	1¾	200
6d	2	.0808	210	.0641	350	5	.2576	13	6d	2	150
7d	2¼	.0858	160	.0641	315	5½	.2893	11	7d	2¼	120
8d	2½	.0935	115	.0720	214	6	.2893	10	8d	2½	85
9d	2¾	.0963	93	.0720	195	6½	.2249	7½	9d	2¾	75
10d	3	.1082	77	.0808	137	7	.2249	7	10d	3	60
12d	3¼	.1144	60	.0808	127	8	.3648	5	12d	3¼	50
16d	3½	.1285	48	.0907	90	9	.3648	4½	16d	3½	40
20d	4	.1620	31	.1019	62	.....	.....	.....	20d	4	20
30d	4½	.1819	22	.....	.....	.....	.....	.....	30d	4½	16
40d	5	.2043	17	.....	.....	.....	.....	.....	40d	5	14
50d	5½	.2294	13	.....	.....	.....	.....	.....	50d	5½	11
60d	6	.2576	11	.....	.....	.....	.....	.....	60d	6	8

TACKS.

Title, Ounce.	Length, Inches.	Number per Pound.	Title, Ounce.	Length, Inches.	Number per Pound.	Title, Ounce.	Length, Inches.	Number per Pound.
1	1/8	16,000	4	7/16	4000	14	13/16	1143
1½	3/16	10,666	6	9/16	2666	16	7/8	1000
2	1/4	8,000	8	5/8	2000	18	15/16	888
2½	5/16	6,400	10	11/16	1600	20	1	800
3	3/8	5,333	12	3/4	1333	22	1 1/16	727
						24	1 1/8	666

WROUGHT SPIKES.

Number to a keg of 150 pounds.

L'gth, Ins.	¼ In., Number.	5/16 In., Number.	⅜ In., Number.	L'gth, Ins.	¼ In., Number.	5/16 In., Number.	⅜ In., Number.	7/16 In., Number.	½ In., Number.
3	2250	....	....	7	1161	662	482	445	306
3½	1890	1208	....	8	....	635	455	384	256
4	1650	1135	....	9	....	573	424	300	240
4½	1464	1064	....	10	....	....	391	270	222
5	1380	930	742	11	....	....	....	249	203
6	1292	868	570	12	....	....	....	236	180

WEIGHT OF COPPER NAILS.

Cut Copper Slating Nails.

1¼ inch, about 190 to the pound.

1½ inch, about 135 to the pound.

Cut Yellow Metal Slating Nails.

1¼ inch, about 154 to the pound.

1½ inch, about 140 to the pound.

Copper Wire Slating Nails.

⅞	inch	No.	12	gauge	about	303	per	pound.
1	"	"	12	"	"	270	"	"
1¼	"	"	11	"	"	196	"	"
1½	"	"	10	"	"	134	"	"
1¼	"	"	12	"	"	231	"	"
1½	"	"	12	"	"	210	"	"

NUMBER OF BOAT SPIKES TO 200-POUND KEG.

Length, Inches.	Diameter.						
	¼ Inch Square.	5/16 Inch Square.	⅜ Inch Square.	7/16 Inch Square.	½ Inch Square.	⅝ Inch Square.	¾ Inch Square.
3	3300	....	....	....	....	....	....
3½	2880	....	....	....	....	....	....
4	2343	1671	....	....	....	....	....
4½	2200	1364	1039	....	....	....	....
5	2030	1308	935	....	....	....	....
5½	1828	1175	880	....	....	....	....
6	1624	1115	710	562	433	....	....
7	1420	988	665	516	400	....	....
8	1220	849	602	453	337	....	....
9	....	....	519	409	305	....	....
10	....	....	468	369	297	182	....
12	....	....	410	302	241	155	....
14	....	....	....	....	216	130	95
16	....	....	....	....	182	122	80

NUMBER AND DIAMETER OF WOOD SCREWS.

Number.	Diameter.	Number.	Diameter.	Number.	Diameter.	Number.	Diameter.
0	.056	8	.162	16	.268	24	.374
1	.069	9	.175	17	.281	25	.387
2	.082	10	.188	18	.293	26	.401
3	.096	11	.201	19	.308	27	.414
4	.109	12	.215	20	.321	28	.427
5	.122	13	.228	21	.334	29	.440
6	.135	14	.241	22	.347	30	.453
7	.149	15	.255	23	.361		

Timber.—DESCRIPTION OF THE VARIOUS WOODS USED IN CONSTRUCTION.—*White Pine*, or Northern pine, is found in the northern part of the United States and in Canada. It is a light, soft, straight-grained wood of a light yellowish color; it is mostly used in buildings for trim and mouldings, where the work is to be painted or stained. It is one of the most reliable of woods for staying in place after it is put up, as it does not twist and warp like some of the other woods.

Georgia Pine, which is also known as pitch or hard pine, and is usually specified as "long-leaf pine," is found along the southern coast of the United States, from Virginia to Texas; it is the best variety of the yellow pine, and is much used for flooring, and also for heavy framing. It is a very strong wood and contains much resin. It should not be used under ground or in damp places, as it decays very fast in such places. The other species of yellow pine are often sold as Georgia "long-leaf," but they are much softer and not so strong. The superintendent should make himself familiar with the different species so as to be able to distinguish them.

Spruce is the name given to all the varieties of the spruce-fir tree, of which there are four: white, black, Norway, and single spruce. Spruce is a very tough light wood, with a reddish color, and is much used for framing lumber; it is also much used for piles, as it preserves well in the water or in damp places.

Oregon Pine.—This is the best framing lumber found in the United States. It is much harder and stronger than the white pine and does not contain as much resin as the yellow pine. It can be got in any size and length and is much used for masts and spars.

Hemlock is similar to spruce in appearance, but is a much inferior wood. It is very brittle, splits very easily, and is often

found shaky. The grain is very coarse and the concentric circular layers of the wood separate easily. It is only used as a cheap framing lumber, and for sheathing, as it holds a nail better than the soft pine.

White Cedar is a soft white, fine-grained wood, and is very durable when exposed to dampness, hence it makes good shingles, for which purpose it is much used.

Red Cedar is a similar wood to the white cedar, but is of a reddish-brown color. It possesses a strong odor which repels insects, and on this account is much used for making chests, lining wardrobes, etc. It is also a good wood for use in damp places, as it stands the moisture very well.

Cypress is a wood somewhat similar to cedar, and is much used for shingles, and for use where dampness is to be considered. It is found in the southern and southwestern parts of the United States.

Red Wood, which is the common name given to the Sequoia or "big trees" of California, is a valuable lumber for building purposes where great strength is not necessary. It has great lasting qualities when exposed to dampness and makes the best of shingles. For sills or posts in the ground it is one of the best woods to be found. It makes good weather-boarding or mouldings and takes the paint well. It is of a dull-reddish color and makes a very nice finish when finished natural.

White Oak is the hardest of the several varieties of oak, and is found in the eastern half of the United States. The wood is very heavy, hard, and strong, and is used where strength is desired.

Red Oak is of a more open grain than the white oak and is softer and not so strong. It is more easily worked and is much used for inside finish. Red oak when quarter-sawed makes one of the most pleasing finishes to the eye.

Ash.—This wood grows in the northern part of the United States. It is very heavy and hard, is usually white in color, and is used for finish and for furniture.

Hickory is the heaviest, toughest, hardest, and strongest of all woods found in America. It is very close-grained and is very flexible. It is not used much for building purposes, unless for wedges, pins, and such like.

Locust is a hard, close-grained wood of a yellowish color; its use is principally for posts in the ground or such places, as it is a very lasting wood in damp places.

Black Walnut is a heavy, hard wood of a dark-brown color and has a very nice even grain. On account of its value it is not used much for building purposes, but its use is confined mostly to furniture and cabinet work.

White Walnut (butternut) is a specie of the walnut; the wood is lighter in color and heavier in grain. Its uses are about the same as black walnut.

Cherry—This wood, which is obtained from the wild-cherry tree, is used for interior finish and for furniture. It is hard, close-grained, and very durable; it takes a high polish and stands well, as it is not liable to twist or warp.

Birch is much similar to cherry in structure and in appearance, but it does not stand as well, being more liable to twist and warp.

Maple is a hard, heavy, strong, close-grained wood of a light color. It is one of the best woods in use for flooring, and is much used for this purpose. The "bird's-eye" maple, which is covered with small spots which resemble small knots, is used for finish and for furniture.

Chestnut, which is a soft, coarse-grained wood of a somewhat similar color to oak, is found in the eastern part of the United States. It is not a strong wood, being very brittle, but its lasting qualities are very good. It is used for inside finish and resembles oak. It is also used for outside structures exposed to the weather, on account of its durability.

Poplar (whitewood) is a wood of a yellowish color, soft and brittle, with a close grain. It is used mostly for mouldings or inside finish, frequently to imitate hard woods, as it has a close grain and takes stain well. The sap-wood is nearly white in color.

Mahogany.—This wood comes from the West Indies and Central America, and is very valuable. It is used principally in the manufacture of furniture; also for finishing in the more expensive houses or buildings.

When timber of any kind is to be used in any structure or construction of any kind, it will be the duty of the superintendent to see that it is free from all defects, of which the most common are rot, dry-rot, wind-shakes, splits, bad knots, sap, etc.

In lumber which contains sap, and which has been piled for some time, just after being sawed, and piled without sticking, the sap will usually turn a dark-blue or drab color. This

is "black or blue sap" and is the first stages of "dry-rot," and any lumber in this condition should be rejected.

Lumber which has been cut from trees growing in soft soil or swamps is often found to contain "wind-shakes," caused by the usually rapid growth of the trees and the swaying or bending of the trees by the wind. These shakes are cracks separating the concentric circular rings of the wood.

Heart-shakes, or splits, are the cracks found in the heart of the log, usually caused by the shrinkage of the log, or the heart of the tree or log separating from the outside layers of the wood.

A sound stick of timber when struck a sharp blow with a hammer on the end should give forth a clear ringing sound, and which can be heard by a person placing his ear at the opposite end of the stick. If the sound is dull and faint it is an indication of decay or some defect in the stick.

Timber for posts carrying great weight should be from the heart of the tree, as this is usually the strongest, and the compression strength will be the same on all outside parts of the stick.

Timber for flag-poles or masts should also be from the heart of the tree. If one side of the stick is heart-wood and the opposite side of the stick is wood from out next the bark the unequal shrinkage of the two sides of the stick in length will cause the stick to bow and become crooked.

Timber before being used should be well seasoned either by natural or artificial means. Timber if piled when sawed and strips placed between each layer of timber so as to permit the air to get to all sides of the timber will season for ordinary use in from seven months to two years, according to the kind of wood and the size of the sticks.

When timber is used in any place where shrinkage in the timber may weaken the structure, the superintendent should make sure that the timber has been well seasoned and is perfectly dry.

When lumber of any kind is brought to the work the superintendent should see that it is piled up and covered in a proper manner to protect it from the sun and weather, as good lumber can be very easily spoiled by carelessness in piling or covering.

The shrinkage of timber is shown by the following table:

Cedar	12 to 11.40 inches.
Elm	12 to 11.70 "
Oak	12 to 11.75 "
Pine (white)	12 to 11.80 "
Pine (yellow)	12 to 11.90 "
Pine (yellow long-leaf)	12 to 11.95 "
Redwood (California)	12 to 11.95 "
Spruce	12 to 11.85 "

The working strength of timber as given by the New York Building Code is shown by the following table:

WORKING STRENGTH PER SQUARE INCH IN POUNDS.

Name of Wood.	Direct Compression.		Tension.	Shearing.		Safe Extreme Fibre Stress (Bending).
	With Grain.	Across Grain.		With Fibre.	Across Fibre.	
Oak	900	800	1000	100	600	1000
Yellow pine	1000	600	1200	70	500	1200
White pine	800	400	800	40	250	800
Spruce	800	400	800	50	320	800
Locust	1200	1000	....	100	720	1200
Hemlock	500	500	....	40	275	600
Chestnut	500	1000	....	...	150	800

Lasting Qualities of Wood in the Earth. — Experiments have been made by driving sticks of different woods into the ground, by which it is ascertained that in five years all of those made of oak, elm, fir, ash, soft mahogany, and all varieties of pine were almost totally rotten; larch and teak were decayed on the outside; acacia was only slightly decayed on the outside; hard mahogany and cedar of Lebanon were in good condition; Virginia cedar was as good as when put in. California redwood is also one of the best woods for use in damp places, as it is very slow to decay.

Any wood to be exposed to much dampness should if possible be coated or impregnated with some preservative. The most effectual method of preserving wood from decay is to force the preservative, such as creosote or other mixture, into the pores of the wood. Plants for doing this are found in nearly all the large cities.

For timbers, etc., to be used underground, a coat of coal-tar applied hot is a good method of preserving the wood from rot.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR RECTANGULAR SPRUCE OR WHITE-PINE BEAMS ONE INCH THICK.

The following table has been calculated for extreme fibre stresses of 750 pounds per square inch corresponding to the following values for moduli of rupture recommended by Prof. Lanza, viz.:

Spruce and white pine	3000 lbs.
Oak	4000 "
Yellow pine	5000 "

For oak increase values in table by ⅓. For yellow pine increase values in table by ⅔.

The safe load for any other values per square inch is found by increasing or decreasing the loads given in the table in the same proportion as the increased or decreased fibre stress.

Span in Feet.	Depth of Beam.										
	6 Ins.	7 Ins.	8 Ins.	9 Ins.	10 Ins.	11 Ins.	12 Ins.	13 Ins.	14 Ins.	15 Ins.	16 Ins.
5	600	820	1070	1350	1670	2020	2400	2820	3270	3750	4270
6	500	680	890	1120	1390	1680	2000	2350	2730	3120	3560
7	430	580	760	960	1190	1440	1710	2010	2330	2680	3050
8	380	510	670	840	1040	1260	1500	1760	2040	2340	2670
9	330	460	590	750	930	1120	1330	1560	1810	2080	2370
10	300	410	530	670	830	1010	1200	1410	1630	1880	2130
11	270	370	490	610	760	920	1090	1280	1490	1710	1940
12	250	340	440	560	690	840	1000	1180	1360	1560	1780
13	230	310	410	520	640	780	930	1080	1260	1440	1640
14	210	290	380	480	590	720	860	1010	1170	1340	1530
15	200	270	360	450	560	670	800	940	1090	1250	1420
16	190	260	330	420	520	630	750	880	1020	1180	1330
17	180	240	310	400	490	590	710	830	960	1100	1260
18	170	230	290	370	460	560	670	780	910	1040	1190
19	160	210	280	360	440	530	630	740	860	990	1130
20	150	200	270	340	420	510	600	710	820	940	1070
21	140	190	260	320	390	480	570	670	780	890	1020
22	140	190	240	310	380	460	540	640	740	850	970
23	130	180	230	290	360	440	520	610	710	810	920
24	130	170	220	280	350	420	500	590	680	780	890
25	120	160	210	270	330	410	480	560	660	750	860
26	110	160	210	260	320	390	460	540	630	720	820
27	110	150	200	250	310	370	440	520	610	690	790
28	110	140	190	240	300	360	430	500	580	670	760
29	110	140	180	230	290	350	410	490	560	640	740

To obtain the safe load for any thickness multiply values for 1 inch by thickness of beam.

To obtain the required thickness for any load divide by safe load for 1 inch.

SAFE LOADS FOR RECTANGULAR WOODEN PILLARS (SEASONED).

l = length of pillar in inches;
d = width of smallest side in inches.

Yellow Pine (Southern).	White Oak.	White Pine and Spruce.
$\dfrac{1125}{1+\dfrac{l^2}{1100d^2}}$	$\dfrac{925}{1+\dfrac{l^2}{1100d^2}}$	$\dfrac{800}{1+\dfrac{l^2}{1100d^2}}$

These formulæ give safe loads of one-fourth the ultimate strength for short pillars, decreasing to one-fifth the ultimate for long pillars.

Ratio of Length to Least Side $\frac{l}{d}$.	Safe Loads in Pounds per Square Inch of Section.		
	Yellow Pine (Southern).	White Oak.	White Pine and Spruce.
12	995	818	707
14	955	785	679
16	913	750	649
18	869	715	618
20	825	678	587
22	781	642	556
24	738	607	525
26	697	575	495
28	657	541	467
30	619	509	440
32	583	479	414
34	549	451	390
36	516	425	367
38	487	400	346
40	458	377	326

The Cleveland Building Code gives the following proportions for wood and other columns:

Sec. 14. LENGTH OF COLUMNS, POSTS, AND PIERS.—No free-standing or built-in column, pier, or post shall exceed the following proportions of the least side or diameter to the height without being anchored, stayed, or tied by beams or girders in at least two (2) directions at right angles to each other:

Brick piers.............................. 1: 8
Block stone piers 1:10
Wooden posts, short 1:16

Wooden posts, long........................ 1:24
Cast-iron columns, short.................. 1:20
Cast-iron columns, long................... 1:30
Wrought-iron columns...................... 1:40
Steel columns 1:44

SAFE LOADS IN TONS OF 2000 POUNDS FOR SQUARE WOODEN PILLARS.

Unsupported Length of Column in Feet.	Size of Pillar in Inches.						
	6×6	8×8	9×9	10×10	12×12	14×14	16×16
	WHITE PINE OR SPRUCE.						
6	12.80	....	....	....	....	....	....
8	11.70	22.7	29.6	....	....	....	....
10	10.60	21.3	28.0	35.5	....	....	....
12	9.54	19.8	26.3	33.7	51.1	....	....
14	8.46	18.4	24.7	31.9	49.0	69.6	....
16	7.38	17.0	23.1	30.1	46.8	67.0	91.0
18	....	15.5	21.5	28.3	44.7	64.5	88.0
20	....	14.1	19.8	26.5	42.5	62.0	85.2
22	....	....	18.2	24.7	40.3	59.5	82.3
24	....	....	....	22.9	38.2	57.0	79.4
	WHITE OAK.						
6	14.80	....	....	....	....	....	....
8	13.50	26.2	34.0	....	....	....	....
10	12.20	24.6	32.4	41.0	....	....	....
12	11.00	22.7	30.4	39.1	59.1	....	....
14	9.73	21.1	28.4	36.7	56.9	80.4	....
16	8.64	19.5	26.5	34.6	54.0	77.8	105.0
18	....	17.8	24.7	32.4	51.1	74.5	102.0
20	....	16.3	22.7	30.5	49.1	71.3	98.5
22	....	....	21.1	28.2	46.1	68.3	94.7
24	....	....	....	26.4	43.9	65.5	90.9
	YELLOW PINE (SOUTHERN).						
6	18.0	....	....	....	....	....	....
8	16.4	32.0	41.6	....	....	....	....
10	14.9	29.9	39.4	50.0	....	....	....
12	13.3	27.8	36.9	47.6	72.0	....	....
14	11.9	25.8	34.7	44.7	69.1	98.0	132.0
16	10.4	23.7	32.3	42.3	65.5	94.6	128.0
18	....	21.8	30.0	39.5	62.6	90.7	124.0
20	....	19.8	27.8	37.0	59.8	86.9	120.0
22	....	....	25.7	34.6	56.2	83.6	115.0
24	....	....	....	32.2	53.3	80.0	111.0

As a guide to the superintendent for inspection of lumber of various kinds the rules for inspection of the different lumber associations are given as follows:

SOUTHERN LUMBER MANUFACTURERS' ASSOCIATION.

RULES FOR THE GRADING AND CLASSIFICATION OF YELLOW PINE.

General Instructions.—1. Yellow-pine Lumber shall be graded and classified according to the following rules and specifications as to quality, and dressed stock shall conform to the subjoined table of standard sizes, *except where otherwise expressly stipulated between buyer and seller.*

2. Recognized defects in yellow pine are knots, knot-holes, splits (either from seasoning ring hearts or rough handling), shake, wane, red heart, rot, rotten streaks, worm-holes, pitch streaks, pitch pockets, solid pitch, torn grain, loosened grain, seasoning or kiln checks, and black or blue sap-stains.

3. Knots.—Knots shall be classified as pin, standard, and large, as to size; and round and spike, as to form; and as sound, loose, encased, pith and rotten, as to quality.

4. A pin knot is sound and not over ½ inch in diameter.

5. A standard knot is sound and not over 1½ inches in diameter.

6. A large knot is sound and any size over 1½ inches in diameter.

7. A round knot is oval or circular in form, and the mean or average diameter of the same shall be considered in applying and construing the rules.

8. A spike knot is one sawn in a lengthwise direction.

9. A sound knot is one solid across its face, is as hard as the wood it is in, may be either red or black, and is so fixed by growth or position that it will retain its place in the piece.

10. A loose knot is one not held firmly in place by growth or position.

11. A pith knot is a small, sound knot with a pith-hole not more than ¼ inch in diameter in the centre.

LUMBER MEASURE.

Inches Wide.	Length in Feet.						
	12	14	16	18	20	22	24
1× 8	8	9	11	12	13	15	16
1×10	10	12	13	15	17	18	20
1×12	12	14	16	18	20	22	24
2× 3	6	7	8	9	10	11	12
2× 4	8	9	11	12	13	15	16
2× 6	12	14	16	18	20	22	24
2× 8	16	19	21	24	27	29	32
2×10	20	23	27	30	33	37	40
2×12	24	28	32	36	40	44	48
2×14	28	33	37	42	47	51	56
2×16	32	37	43	48	53	59	64
3× 4	12	14	16	18	20	22	24
3× 6	18	21	24	27	30	33	36
3× 8	24	28	32	36	40	44	48
3×10	30	35	40	45	50	55	60
3×12	36	42	48	54	60	66	72
3×14	42	49	56	63	70	77	84
3×16	48	56	64	72	80	88	96
4× 4	16	19	21	24	27	29	32
4× 6	24	28	32	36	40	44	48
4× 8	32	37	43	48	53	59	64
4×10	40	47	53	60	67	73	80
4×12	48	56	64	72	80	88	96
6× 6	36	42	48	54	60	66	72
6× 8	48	56	64	72	80	88	96
6×10	60	70	80	90	100	110	120
6×12	72	84	96	108	120	132	144
6×14	84	98	112	126	140	154	168
6×16	96	112	128	144	160	176	192
8× 8	64	75	85	96	107	117	128
8×10	80	93	107	120	133	147	160
8×12	96	112	128	144	160	176	192
8×14	112	131	149	168	187	205	224
8×16	128	149	171	192	213	235	256
10×10	100	117	133	150	167	183	200
10×12	120	140	160	180	200	220	240
12×12	144	168	192	216	240	264	288

12. An incased knot is one surrounded wholly or in part by bark or pitch.

13. A rotten knot is one not as hard as the wood it is in.

14. Pitch.—Pitch pockets are openings between the grain of the wood containing more or less pitch or bark, and shall be classified as large and small pitch pockets.

15. A standard pitch pocket is one not over $\frac{3}{8}$ of an inch in open width or 3 inches in length.

A small pitch pocket is one less than $\frac{1}{8}$ of an inch in open width.

16. A pitch pocket showing open on both sides of the piece

LUMBER MEASURE.

Inches Wide.	Length in Feet.							
	26	28	30	32	34	36	38	40
2× 3	13	14	15	16	...	...	...	...
2× 4	17	19	20	21	23	24	25	27
2× 6	26	28	30	32	34	36	38	40
2× 8	35	37	40	43	45	48	51	53
2×10	43	47	50	53	57	60	63	67
2×12	52	56	60	64	68	72	76	80
2×14	61	65	70	75	79	84	89	93
2×16	69	75	80	85	91	96	101	107
3× 4	26	28	30	32	34	36	38	40
3× 6	39	42	45	48	51	54	57	60
3× 8	52	56	60	64	68	72	76	80
3×10	65	70	75	80	85	90	95	100
3×12	78	84	90	96	102	108	114	120
3×14	91	98	105	112	119	126	133	140
3×16	104	112	120	128	136	144	152	160
4× 4	35	37	40	43	45	48	51	53
4× 6	52	56	60	64	68	72	76	80
4× 8	69	75	80	85	91	96	101	107
4×10	87	93	100	107	113	120	127	133
4×12	104	112	120	128	136	144	152	160
6× 6	78	84	90	96	102	108	114	120
6× 8	104	112	120	128	136	144	152	160
6×10	130	140	150	160	170	180	190	200
6×12	156	168	180	192	204	216	228	240
6×14	182	196	210	224	238	252	266	280
6×16	208	224	240	256	272	288	304	320
8× 8	139	149	160	171	181	192	203	213
8×10	173	187	200	213	227	240	253	267
8×12	208	224	240	256	272	288	304	320
8×14	243	261	280	299	317	336	355	373
8×16	277	299	320	341	363	384	405	427
10×10	217	233	250	267	283	300	317	333
10×12	260	280	300	320	340	360	380	400
12×12	312	336	360	384	408	432	456	480

$\frac{1}{8}$ of an inch or more in width shall be considered the same as a knot-hole.

17. A pitch streak is a well-defined accumulation of pitch at one point in the piece, and when not sufficient to develop a well-defined streak, it shall not be considered a defect.

18. A small pitch streak shall be equivalent to not over one-twelfth the width and one-sixth the length of the piece it is in.

A standard pitch streak shall be equivalent to not over one-sixth the width and one-third of the length of the piece it is in.

19. SAP.—Bright sap shall not be considered a defect in any of the grades provided for and described in these rules.

The restriction or exclusion of bright sap constitutes a special class of material which can only be secured by *special contract.*

20. Blued sap shall not be considered a defect in any of the grades of common lumber.

21. MISCELLANEOUS.—Firm red heart shall not be considered a defect in any of the grades of common lumber.

22. Defects in rough stock caused by improper manufacture and drying will reduce grade, unless they can be removed in dressing such stock to standard sizes.

23. All stock shall be inspected on the face side to determine the grade. For stock surfaced one side the dressed surface shall be considered the face side. And for stock rough or dressed two sides, the best side shall be considered the face, but the reverse side of all such stock should not be more than one grade lower.

24. Imperfect manufacture in dressed stock, such as torn grain, loosened grain, broken knots, mismatched, insufficient tongue or groove on flooring, ceiling, drop-siding, etc., shall be considered defects, and will reduce grade according as they are slight or serious in their effects on the use of the stock.

25. Pieces of either flooring, ceiling, or drop-siding having less than $\frac{3}{16}$ inch of tongue shall not be admitted in any grade above No. 2 Common, pieces with $\frac{3}{16}$ inch or more of tongue to be admitted in any grade.

26. In all grades of flooring, ceiling, drop-siding, etc., wane on the reverse side, not exceeding one-third the width and one-sixth the length of any piece, provided the wane does not extend into the tongue, nor over one-half the thickness below the groove, is admissible.

27. Chipped grain consists in a part of the surface being chipped or broken out in small particles below the line of the cut, and as usually found should not be classed as torn grain and shall not be considered a defect.

28. Torn grain consists in a part of the wood being torn out in dressing. It occurs around knots and curly places.

29. Loosened grain consists in a point of one grain being torn loose from the next grain. It occurs on the heart side of the piece, and is a serious defect, especially in flooring.

30. The grade of all regular stock shall be determined by the number, character, and position of the defects visible in any piece. The enumerated defects admissible in any grade are

intended to be descriptive of the *coarsest* pieces *such grades may contain.* The average quality of the grade should be about midway between such pieces and the coarest pieces allowed in the next higher grade.

31. Lumber and timber sawed for specific purposes must be inspected with a view to its adaptability for the use intended. Material not conforming to standard sizes, for agricultural-implement companies, wagon companies, car-manufacturing companies, railway companies, etc., shall be governed by special contact.

32. The standard lengths are multiples of two feet, ten to twenty-four feet, inclusive, for boards, stripes, dimension, joists, and timbers. Longer or shorter lengths than those herein specified are special. Odd and fractional lengths shall be counted as of the next higher even length.

33. On stock-width shipments of No. 1 Common and better lumber, either rough or dressed one or two sides, no piece shall be admissible that is more than $\frac{1}{4}$ inch scant on 8-inch and under; $\frac{3}{8}$ inch scant on 10-inch, or $\frac{1}{2}$ inch scant on 12-inch or wider. All 4-inch and wider No. 2 Common stock may go $\frac{1}{2}$ inch scant in width.

34. Yellow pine of a better grade than No. 1 Common, up to 4 inches in width, shall be classified as to grain as edge grain and flat grain.

Edge grain has been variously designated as rift sawn, vertical grain, quarter sawn, all being commercially synonymous terms. Edge-grain stock is especially desirable for flooring and admits no piece in which the angle of the grain exceeds 45 degrees from verticle at any point, thus excluding all pieces that will sliver or shell from wear. Such as will not meet these requirements shall be known as flat grain.

35. *All dressed stock shall be measured and sold strip count, viz., full size of rough material necessarily used in its manufacture.*

All sizes 1 inch or less in thickness shall be counted as 1 inch thick.

36. Equivalent means equal, and in construing and applying these rules, the defects allowed, whether specified or not, are understood to be equivalent in damaging effect to those mentioned applying to stock under consideration.

37. The foregoing general observations shall apply to and govern the application of the following rules:

Dressed Yellow-pine Finishing.—Grades: First and Second Clear, Third Clear.

38. *First and Second Clear.* Inch, $1\frac{1}{4}$, $1\frac{1}{2}$, and 2-inch, dressed one or two sides up to and including 8 inches wide, must show one face practically clear of all defects. 10 inches wide will admit any one of the following defects: One split not more than 6 inches long, one small pitch pocket, one pin knot, pitch streak, or blue sap stain not to exceed the equivalent of 6 square inches. One-third of any shipment of 12- and 14-inch in addition to one straight split not to exceed in length the width of the piece will admit any one of the following defects or its equivalent: Three pin knots, one standard knot, two small pitch pockets, or one large pitch pocket, one small pitch streak, small kiln or seasoning checks, one blue sap stain $1\frac{1}{2}$ inches wide running across the face of the piece.

Each two inches above 14 inches in width, in addition to one straight split, not to exceed in length the width of the piece, will admit any two of the defects allowed in 12-inch or their equivalent. Pieces otherwise admissible which have loosened or torn grain on the face side shall be put in a lower grade.

39. *Special.*—In case both sides are desired clear special contract must be made. Defective dressing on the reverse side of finishing is admissible.

40. *Third Clear.*—Inch, $1\frac{1}{4}$, $1\frac{1}{2}$, and 2-inch, dressed two sides up to and including 10 inches in width, in addition to one straight split not to exceed in length the width of the piece, may have any two of the following defects or their equivalent: Slight torn grain, three pin knots, one standard knot, three small pitch pockets, one standard pitch pocket, one standard pitch streak, three blue sap stains 2 inches wide across the face or blue sap not over 8 inches deep on one end, wane not to exceed 1 inch in width and $\frac{1}{6}$ the length of the piece, or small kiln or seasoning checks. Twelve or 14 inches will admit three of the above defects or their equivalent.

Flooring.—Grades: A, B, and C Flat, A, B, and C Edge Grain, No. 1 and 2 Fence.

Special Section.—Defects named in Flooring and Ceiling are based upon a piece manufactured from $1\times4-12$, and pieces larger or smaller than this will take a greater or less number of defects, proportioned to their size on this basis.

41. *A Flat Flooring* must be practically free from defects on the face side and well manufactured.

42. *B Flat Flooring* may have any two of the following defects or their equivalent: Blue sap stain not to exceed 15 per cent of the face, three pin knots, one standard knot, three small pitch pockets, one standard pitch pocket, one standard pitch streak, slight torn grain, or small kiln or seasoning checks.

Pieces otherwise good enough for A, but containing not over *six small pinworm-holes* that have no blue sap about them, shall be admitted in B.

43. *Edge-grain Flooring* shall take the same inspection as flat grain, except as to the angle of the grain.

43½. *Heart-face Edge Grain* shall be free from sap on face side.

43¾. *Flat-grain C Flooring* shall consist of stock that falls below a B grade of flooring in working B and better strips, and will admit of any two of the following or their equivalent of combined defects: 60 per cent of blue sap, pitch streak, or firm red heart; chipped or torn grain not over $\frac{1}{16}$ inch deep in three places in one piece, or other machine defects that will lay without waste; shake or seasoning checks that do not go through, two standard pitch pockets, or six small pitch pockets, twenty pinworm-holes, two standard or six pin knots, or two pith knots; pieces otherwise as good as "A" can have one defect (as a knot-hole) that can be cut out by wasting 1½ inches of the length of the piece.

44. *No. 1 Fence Flooring* may contain the following defects or their equivalent: Sound knots not over one-half the width of the piece at any one point throughout its length; spike knots whose length is not over one-half the width of the piece, and if on the edge not to exceed one-half the thickness; three pith knots, pitch, pitch pockets, blue sap, firm red heart, seasoning checks or slight shake, twenty pinworm-holes, chipped, loosened, or torn grain not over ⅛ inch deep in three places in a piece, or other machine defects that will lay without waste; and if otherwise as good as "B" one defect (like a knot-hole) that can be cut out by wasting 3 inches of the length of the piece.

45. *No. 2 Fence Flooring* admit sall pieces that will not grade as good as No. 1 Fence Flooring, that can be used for cheap floors or sheathing without a waste of more than one-fourth

the length of any one piece, and admits all the defects named in No. 2 Common Fencing.

46. *Centre Matched Flooring* shall be required to come up to grade on face side only.

CEILING.—Grades: A, B, No. 1 and No. 2 Common.

47. *A Ceiling* must be practically free from defects on the face side and well manufactured.

48. *B Ceiling* will admit of any two of the following defects or their equivalent: Slight torn grain, three pin knots, one standard knot, three small pitch pockets, one standard pitch pocket, one small pitch streak, seasoning or kiln checks that do not go through, blue sap stain or firm red heart not to exceed 15 per cent of the face.

Pieces otherwise good enough for A, but containing not over *six small pinworm-holes* that have no blue sap about them, shall be admitted in B.

49. *No. 1 Common Ceiling* will admit sound knots not over one-half the width of piece in the rough, blue sap, pitch streaks, pitch pockets, firm red heart, slight shake, torn grain, kiln or seasoning checks, or defects in manufacture.

Pieces otherwise good enough for A, but containing one loose or unsound knot or knot-hole, 1½ inches in diameter or less, shall be graded No. 1 Common.

Pieces otherwise good enough for A, but containing not over *ten small pinworm-holes* that have no blue stain about them, shall be graded No. 1 Common.

Pieces otherwise good enough for A, but containing one pith knot, shall be admitted in the grade of No. 1 Common.

50. *No. 2 Common Ceiling* admits of all pieces not as good as No. 1 Common that can be used without waste of more than one-fourth the length of any one piece.

WAGON-BOTTOMS.—Grades: A and B.

51. *Wagon-bottoms* unless otherwise ordered (see section 31) shall be graded the same as A and B Flat Flooring.

DROP-SIDING.—Grades: A, B, and No. 1 Common.

52. *A Drop-siding* must be practically free from defects on the face side and well manufactured.

53. *B Drop-siding* will admit any two of the following defects or their equivalent: Slight-torn grain, three pin knots, one standard knot, blue sap stain or firm red heart not to exceed 15 per cent of the face, and slight kiln and seasoning checks.

Pieces otherwise good enough for A, but containing not over

six small pinworm-holes that have no blue sap about them, shall be admitted in B.

54. *No.* 1 *Common Drop-siding* will admit one standard pitch streak or one large pitch pocket, or their equivalent; and in addition, sound knots not over one-half the width of piece in the rough, blue sap stain, firm red heart, slight shake, torn grain, defects in manufacture, and kiln or seasoning checks that do not go through the piece.

Pieces otherwise good enough for A, but containing one loose or unsound knot or knot-hole 1½ inches in diameter or less, shall be graded No. 1 Common.

Pieces otherwise good enough for A, but containing not over *ten small pinworm-holes* that have no blue stain about them, shall be graded No. 1 Common.

Pieces otherwise good enough for A, but containing one pith knot, shall be admitted in the grade of No. 1 Common.

Bevel-siding.—Grades: A, B, and No. 1 Common.

55. *Bevel-siding* shall be graded according to the rules for drop-siding, and will admit in addition slight imperfections on the thin edge, which will be covered by the lap when laid 4½ inches to the weather.

Partition.—Grades: A, B, and No. 1 Common.

56. *Partition* shall be graded according to ceiling rules, and must meet the requirements of the specified grades on the face side only, but the reverse side shall not be more than one grade lower.

Moulded Casing and Base. Window- and Door-jambs.—Grades: A and B.

57. *A Moulded Casing and Base* must be practically free from defects on the face side and well manufactured.

58. *B Casing or Base* consists of rejections made after dressing stock inspected in the rough as "A." The defects admitted in B Ceiling shall be allowed.

Window- and Door-jambs shall be graded the same as moulded casing and base.

See section No. 35 for width.

Common Boards, Shiplap, and Barn Siding, 8, 10, and 12 Inches Wide.—Grades: No. 1, No. 2, and No. 3 Common.

59. *No.* 1 *Common Boards*, dressed one or two sides, and *No.* 1 *Common Shiplap* and *Barn Siding* shall be well manufactured; will admit any number of sound knots, not over one-

fourth of the width of the piece if located at the edge, nor over one-third of the width of the piece if located away from the edge; or their equivalent spike knots—provided, however, that the spike knots when located on the edge do not occupy more than one-half the thickness of said edge—two pith knots, one straight split not to exceed in length the width of the piece, pitch, pitch pockets, blue sap, seasoning checks that do not go through, firm red heart, wane ½ inch deep on edge, and one-third the length of the piece or its equivalent, and a limited number of small pinworm-holes well scattered. These boards should be firm and strong and suitable for use in all ordinary construction.

GROOVED ROOFING.—*Grooved Roofing* shall be graded by rules governing No. 1 Boards, omitting the pith knots, worm-holes, and splits in end.

60. *No. 2 Common Boards*, dressed one or two sides, and *No. 2 Common Shiplap, No. 2 Common Grooved Roofing* may contain any number of knots, none of which are over 4½ inches in diameter, or their equivalent spike knots, worm-holes, one straight split one-fourth the length of the piece, but must be free from through-rotten streaks, through-heart shakes over one-half of the length of the piece, and wane over 2 inches wide exceeding one-half the length of the piece.

A knot-hole 1½ inches in diameter, or its equivalent in small knot-holes or rotten streaks, will be allowed, provided the piece is otherwise as good as No. 1 Common.

FENCING, 3, 4, AND 6 INCHES WIDE.—Grades: No. 1, 2, and 3 Common.

61. *No. 1 Fencing* may contain the following defects or their equivalent: Sound knots, not over one-half width of piece at any point throughout its length; spike knots whose length is not over one-half the width of the piece, and if on the edge not to exceed one-half the thickness, three pith knots or their equivalent, wane one-half inch deep on edge and one-half of the length of the piece, pitch, pitch pockets, blue sap, seasoning checks, firm red heart, and a limited number of small pinworm-holes well scattered.

62. *No. 2 Fencing*, in addition to the defects allowed in No. 1 Common, will admit the following defects or their equivalent. Knots that do not badly weaken the piece at any point, small, unsound or loose knots, one straight split one-fourth the length of the piece, worm-holes, rotten streaks that do not

go through; shake and wane, but must be good enough to be used in full length as fencing.

A knot-hole $1\frac{1}{2}$ inches in diameter or its equivalent in small hollow knots will be allowed, provided the piece is otherwise as good as No. 1 Common.

63. *No.* 3 *Fencing* and *No.* 3 *Boards* are defective lumber, and will admit of coarse knots, knot-holes, very wormy pieces, some red rot and other defects that will not prevent its use as a whole for cheap sheathing or cutting one-half its length as No. 2 Common.

64. Miscut 1-inch boards and fencing which do not fall below $\frac{3}{4}$ inch in thickness shall be admitted in No. 2 Common, provided the grade of such thin stock is otherwise as good as No. 1 Common.

DIMENSION. S. 1 S. 1 E.—Grades: No. 1, No. 2, and No. 3 Common.

65. Inspection of dimension is a question of strength and uniformity of size, and whatever reduces its strength in cross-section must be considered a defect to that extent.

66. *No.* 1 *Common Dimension* may contain sound knots, none of which in 2×4s should be larger than 2 inches in diameter on one or both sides of the piece, and on wider stock which does not occupy more than one-third of the cross-section at any point throughout its length if located at the edge of the piece, or more than one-half of the cross-section if located away from the edge; two pith knots, or smaller or more defective knots which do not weaken the piece more than the knot aforesaid; will admit of seasoning checks, firm red heart, heart-shakes that do not go through, wane, pitch, blue sap stains, pitch pockets, splits in ends not exceeding in length the width of the piece, a limited number of small pinworm-holes well scattered, and such other defects as do not prevent its use as substantial structural material.

67. *No.* 2 *Common Dimension* may have knots which do not occupy more than one-half of the cross-section at any one point if located at the edge of the piece, nor more than two-thirds of the cross-section if located away from the edge; smaller, loose, hollow, or rotten knots that do not weaken the piece more than the knots aforesaid; will admit rotten streaks, shake, wane, worm-holes, and other defects which do not prevent its use without waste.

68. *No.* 3 *Dimension* will include all pieces falling below

No. 2 grade which are sound enough to use for cheap building material.

69. Miscut 2-inch stock which does not fall below 1½ inches in thickness shall be admitted in No. 2 Common, provided such pieces are in all other respects as good as No. 1 Common.

70. Rough Yellow Pine Finishing. — Finish must be evenly manufactured, and shall embrace all sizes from 1 to 2 inches in thickness by 4 inches and over in width.

71. No inch, 1¼ and 1½ finishing lumber, unless otherwise ordered, shall measure when dry more than $\frac{1}{16}$ inch scant in thickness and on 2-inch it may be ⅛ inch scant.

72. Wane and seasoning checks that will dress out in working to standard thickness and widths are admissible.

73. Subject to the foregoing provisions, rough-finishing shall be graded according to the specifications applying to dressed finishing lumber.

All rough finishing lumber, if thicker than specified thickness for dry or green stock, may be dressed to such standard thickness, and when so dressed shall be considered as rough stock.

When like grade on both faces is required, *special contract* must be made.

74. Common Boards, Fencing, and Dimension.—Rough common boards and fencing must be well manufactured, and should not be less than ⅞ inch thick when dry.

75. Rough 2-inch common shall be well manufactured and not less than 1⅞ inches thick when green, or 1¾ inches thick when dry. The several widths must not be less than ⅛ inch over the standard dressing width for such stock.

Rough common dimension of a greater thickness than 2 inches and less than 4 inches shall be subject to special contract as to thickness and width.

76. *Rough Dimension,* if thicker than specified thickness for dry or green stock, may be dressed to such standard thickness, and when so dressed shall be considered as rough stock.

77. The defects admissible in rough boards, fencing, and dimension shall be the same as those applying to dressed stock of like kind and grade, and such further defects as would disappear in dressing to standard sizes of such material shall be allowed.

78. No. 1 Common Timbers.—*Rough Timbers,* 4×4 and larger, shall not be more than ¼ inch scant when green, and

be well manufactured, with not less than three square edges, and must be free from knots that will materially weaken the piece.

Timbers 10×10 in size may have a 2-inch wane on one corner, measured on faces, or its equivalent on two or more corners, one-third the length of the piece. Larger sizes may have proportionately greater defects.

Shakes extending not over one-eighth of the length of the piece are admissible, and seasoning checks shall not be considered a defect.

79. Dressed timbers shall conform in grading to the specifications applying to rough timbers of same size.

80. Rough timbers, if thicker than specified thickness for dry or green stock, may be dressed to such standard thickness and when so dressed shall be considered as rough stock.

STANDARD SIZES OF DRESSED LUMBER.—*Finishing.*—1-inch S. 1 S. or 2 S. to $\frac{13}{16}$, $1\frac{1}{4}$ inch S. 1 S. or 2 S. to $1\frac{3}{32}$, $1\frac{1}{2}$ inch S. 1 S. or 2 S. to $1\frac{11}{32}$, 2 inch S. 1 S. or 2 S. to $1\frac{3}{4}$ inches.

Moulded Casing and Base.—$\frac{13}{16}$ to patterns as per Southern Lumber Manufacturers' Association Moulding Book, 1901 edition. 1×4 S. 4 S. shall be $3\frac{1}{2}$ inches wide, finished, and 1×6 S. 4 S. shall be $5\frac{1}{2}$ inches wide, finished.

Flooring.—The standard of 1×3, 1×4, and 1×6 inches shall be $\frac{13}{16}\times2\frac{1}{4}$, $3\frac{1}{4}$, and $5\frac{1}{4}$ inches, $1\frac{1}{4}$-inch flooring shall be $1\frac{3}{32}$ inches thick.

Drop Siding.— D. and M. $\frac{3}{4}\times3\frac{1}{4}$ and $5\frac{1}{4}$ inches; shiplap, $\frac{3}{4}\times5$ inch face, $5\frac{1}{2}$ over all.

Partition.—$\frac{3}{4}\times3\frac{1}{4}$ and $5\frac{1}{4}$ inches.

Ceiling.—$\frac{3}{8}$-inch ceiling, $\frac{5}{16}$ inch; $\frac{1}{2}$-inch ceiling, $\frac{7}{16}$ inch; $\frac{5}{8}$-inch ceiling, $\frac{9}{16}$ inch; $\frac{3}{4}$-inch ceiling $\frac{11}{16}$ inch. Same width as flooring. The bead on all ceiling and partition shall be depressed $\frac{1}{32}$ of an inch below surface line of piece.

Bevel Siding.—To be made from stock S. 4 S. to $\frac{13}{16}\times5\frac{1}{2}$ and resawed on a bevel.

Window- and Door-jambs.—(See section 35.)

Dressed, rabbeted, and ploughed as ordered, worked $\frac{3}{8}$ inch scant of width.

Boards and Fencing.—1-inch S. 1 S. or 2 S. to $\frac{13}{16}$ inch.

Shiplap.—8-, 10-, and 12-inch. $\frac{13}{16}\times7\frac{1}{8}$, $9\frac{1}{8}$, and $11\frac{1}{8}$ inches.

D. and M.—8-, 10-, and 12-inch. $\frac{13}{16}\times7\frac{1}{8}$, $9\frac{1}{8}$, and $11\frac{1}{8}$ inches.

Grooved Roofing.—10- and 12-inch S. 1 S. and 2 E. to $\frac{13}{16}\times9\frac{1}{2}$ and $11\frac{1}{2}$.

Wagon-bottoms, unless otherwise ordered (see section 31), shall be made in sets 38 and 42 inches face and from stock 4 inches or over in width.

Dimension.—2×4 D. 1 S. and 1 E. to $1\frac{5}{8}\times3\frac{5}{8}$ inches; 2×6 D. 1 S. and 1 E. to $1\frac{5}{8}\times5\frac{5}{8}$ inches; 2×8 D. 1 S. and 1 E. to $1\frac{5}{8}\times7\frac{1}{2}$ inches; 2×10 D. 1 S. and 1 E. to $1\frac{5}{8}\times9\frac{1}{2}$ inches; 2×12 D. 1 S. and 1 E. to $1\frac{5}{8}\times11\frac{1}{2}$ inches; 4×4 and 4×6 D. 1 S. and 1 E. to $\frac{3}{8}$ inch off side and edge; S. 4 S. $\frac{1}{4}$ inch off each side.

SOUTHERN CYPRESS LUMBER ASSOCIATION.

In effect February 22, 1897.

Strips.—4″ to 6″ strips shall be graded A, B, C, D, and read the same as flooring grades.

Siding.—"Clear and A" Siding may have 1″ of bright sap on thin edge, and may contain one small sound knot.

"B" may have $\frac{1}{3}$ of face bright sap if otherwise clear, or in lieu of $\frac{1}{3}$ sap may contain two small sound knots.

"C" may be all bright sap or may have one to five knots, the whole not aggregating over 3″, or knots or other defects that can be removed in two cuts with waste not exceeding 12″ in length, or three pinworm-holes, and may have check or split at one end, not exceeding 12″ in length.

"D" may have stained sap and pinworm-holes, or may have other defects that will not cause a waste to exceed $\frac{1}{3}$ the piece.

DRESSED FINISHING.—Seven inches (7″) and up random width to be two grades, as described in 1*st and* 2*d Clear and Select.*

FLOORING, CEILING, AND PARTITION.—Clear must be free of sap and defects.

"A" may have 1″ bright sap on one edge, may contain one small sound knot, or may have bright sap $\frac{1}{4}$ its width on one end for not exceeding two feet from end.

"B" may have $\frac{1}{3}$ of its face bright sap if otherwise clear, or in lieu of bright sap contain two small sound knots, or may have a split not to exceed 9″ at one end.

"C" may have all bright sap, or may have one to five knots, the whole not aggregating over 3″, or knots or other defects that can be removed in two cuts with waste not to exceed 12″ in length, or may have three pinworm-holes, or may have check or split at one end not to exceed 12″ in length.

"D" may have stained sap and pinworm-holes, or may have unsound knots or other defects that will not cause a waste to exceed $\frac{1}{3}$ of the piece.

DRESSED FINISHING.—Strips 1, $1\frac{1}{4}$, and $1\frac{1}{2}\times 4$ to 6 inches wide to be graded as 1*st and 2d Clear and Select.* The above 1st and 2d Clear strips, which are 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ thick, shall have one heart face, and will admit one inch sap, on one edge. *Select* may be all bright sap, or in lieu of sap may contain two standard knots. 2×4 and 2×6 to be graded Clear and Select as described in above 1, $1\frac{1}{4}$, and $1\frac{1}{2}$ strips.

SQUARES.—Squares to be graded Clear and Select 4×4 to 10×10. A clear square to admit $\frac{1}{4}$ its size of sap on one corner. Select may have half bright sap.

SHINGLES.—*Best.*—A dimension shingle, 4, 5, and 6 inches, each width separately bunched, sixteen inches long, five butts to measure two inches, all heart free of shakes, knots, and other defects.

Primes.—Dimension, each width separately bunched, sixteen inches long, five butts to measure two inches, admitting tight knots and sap, free of shakes and other defects, but with no knots within eight inches of the butt.

Extra "A."—Same as Primes, except random width and may admit of shingles fourteen inches long.

Clippers.—Any shingles which are sound for five inches from the butts—worm-holes excepted—and two and one-half inches or up in width.

WEIGHTS.

	Pounds per M.
Lumber, rough, 2 inches and under	3000
Lumber, rough, $2\frac{1}{2}$ and 3 inches	3500
$\frac{7}{8}$-inch flooring and ceiling	2300
$\frac{5}{8}$-inch ceiling	1600
$\frac{1}{2}$-inch ceiling	1300
$\frac{3}{8}$-inch ceiling	1000
$\frac{1}{2}$-inch bevel siding	1000
Shingles, all grades	300
$\frac{3}{8}$-inch plaster lath	500
$\frac{5}{8}$-inch fence lath	900
$1\frac{1}{4}\times 1\frac{1}{4}\times 4$ D. & H. pickets	1600
$\frac{7}{8}\times 2\frac{1}{2}\times 4$ D. & H. pickets	1800
2-inch O. G. battens	500
$2\frac{1}{2}$-inch O. G. battens	600
3-inch O. G. battens	700

Gauges for Matched Lumber.—*Flooring.*—1×4 and 1×6 shall be $\frac{27}{32}$ by $3\frac{1}{4}''$ and $\frac{27}{32}\times5\frac{1}{4}''$.

$1\frac{1}{4}''$ flooring shall be $1\frac{3}{32}$.

Ceiling.—$\frac{3}{8}''$ shall be $\frac{5}{16}''$; $\frac{1}{2}''$ shall be $\frac{7}{16}''$; $\frac{5}{8}''$ shall be $\frac{9}{16}''$; $\frac{3}{4}''$ shall be $\frac{11}{16}''$, and the width shall be the same as flooring.

Tank Stock shall be $5''$ and over in width, $1\frac{1}{4}''$ to $4''$ thick. and $8'$ and over long. Pieces up to $7''$ shall be free of sap. Pieces wider than $7''$ may have $1''$ of sound sap on one edge, not to exceed half the length and half the thickness of the piece. In all widths, sound knots that do not impair its usefulness for tank purposes may be admitted.

1st and 2d Clear shall be $8''$ and over in width. Pieces $8''$ to $10''$ may have $1''$ of bright sap on each edge, or its equivalent on one edge, otherwise they must be clear. Pieces $10''$ and under $12''$ wide may have $1\frac{1}{2}''$ of bright sap on each edge, or $3''$ on one edge, and one standard knot $1\frac{1}{4}''$ in diameter.

Pieces $12''$ wide may have one standard knot and $2''$ of bright sap on each edge, or the equivalent on one edge; or in lieu of sap may have two standard knots or their equivalents. Pieces wider than $12''$ may admit of defects in proportion as width increases. Pieces $14''$ and wider may have one straight split not over $10''$ to $12''$ long, when comparatively free from other defects. Slight season checks allowed in above grade.

Selects shall have one face side and be $7''$ and over in width. Pieces $10''$ and under in width shall admit two standard knots of $1\frac{1}{4}''$ in diameter, and an additional standard knot for every two inches in width, over $10''$. Bright sap not considered a defect. Unsound knots that do not go through the piece to be allowed. Pieces free from other defects, $10''$ and over wide, to admit pinworm-holes on one edge one-tenth the width of the piece. Season checks no defect. Slight wane on $10''$ pieces and over, allowed on one side, not over 3 feet in length. When no other defects appear, slight amount stained sap may be allowed. Pieces $10''$ and over in width may have a straight split not to exceed $12''$ in one end, when comparatively free from other defects.

Shop.—Shop to be $6''$ and over in width, $8'$ and over in length, and to include all lumber that will not go into above grades, but that will cut for shop use 60 per cent clear of waste.

MERCHANTABLE OR COMMON may be any width, admitting sap, knots, shake, or peck, when the strength is not impaired.

RULES FOR GRADING EASTERN OREGON WHITE PINE.

Common lumber will be divided into four grades as follows: No. 1 Common, No. 2 Common, No. 3 Common or Sheathing, and No. 4 Common or Culls.

NO. 1 COMMON BOARDS AND STRIPS shall include all sound, tight-knotted stock whether red or black knots, but must be free from large coarse knots that will weaken the piece or loose knots that will fall out in the seasoning or handling. A small amount of blue sap stain is admissible in a piece where the knot defects are not very pronounced.

Ex. 1. No. 1 COMMON 1×12—16 S. 1 S.—Has five red knots from 1½ to 2 in. in diameter, three limb knots or V 1½×3 in., but running in not more than one-half thickness of the board; also twelve small black and red knots all sound and well scattered, these smaller knots varying in size from ½ in. to 1 in. in diameter.

Ex. 2. No. 1 COMMON 1×12—20 S. 1 S.—Has seven red knots from 1½ in. to 2 in. in diameter and five red branch knots extending across not more than one-third the width of the board nor running in not more than one-half the thickness of the board; also several small sound knots from ½ in. to 1¼ in. in diameter. This is a heart board.

Ex. 3. No. 1 COMMON 1×10—16 GROOVED ROOFING.—This piece contains three sound smooth knots from 1½ to 2 in. in diameter and eight small red knots from ½ to 1 in. in diameter and a small amount of blue stain.

Ex. 4. No. 1 COMMON 1×8—16 SHIPLAP OR RUSTIC.—This piece contains three sound red knots from 1¼ in. to 1½ in. in diameter and eight or ten small sound knots and pin knots and will admit of a small amount of blue stain. The piece must work smooth and sound.

Ex. 5. No. 1 COMMON 1×6—16 FENCING S. 1 S.—This piece contains five sound knots from 1 in. to 1½ in. in diameter well scattered and some small sound tight knot sthat will in no way weaken the piece. It will also admit of some blue stain.

Ex. 6. No. 1 COMMON 1×4—16 FENCING S. 1 S.—Has three sound knots from 1 in. to 1½ in. well scattered through the piece and a few smaller sound knots, but none that will impair the

strength of the board. It will also admit of a small streak of blue stain.

No. 2 Common Boards and Strips shall also be sound in appearance, but will admit of larger and coarser knots not necessarily sound and more sap stain than No. 1 Common. It will also admit of larger and coarser V or limb knots, but not so large or so coarse as to weaken the piece or materially impair its strength. It shall be free from knot-holes, rot, or splits, but should a knot on the edge of the board slough off in the milling it will not disqualify it for this grade. It must have a good bearing on both sides. A single split not to exceed 2 feet in length in one end of a piece shall not disqualify it for this grade.

Ex. 1. No. 2 Common 1×12—16 S. 1 S.—Has five knots 2½ to 3 in. in diameter and three limb or V knots and a number of smaller knots and will admit of considerable discoloration. All the knots must be firmly set and the limb knots must not extend more than one-half the width of the piece.

Ex. 2. No. 2 Common 1×12—20 S. 1 S.—Has six knots from 2½ to 3 in. in diameter and five limb or V knots that do not extend across over half the face of the board and a number of smaller knots from ½ to 1½ in. in diameter. All knots firmly set and well distributed. One-third of the face of the piece is slightly stained.

Ex. 3. No. 2 Common 1×10—16 S. 1 S.—Has three round knots 3 in. in diameter and several smaller knots from 1½ to 2 in. in diameter and a number of knots from ½ to 1¼ in. in diameter, but all well scattered and firmly set.

Ex. 4. No. 2 Common 1×8—16 S. 1 S.—Has several red and black knots from 2 in. to 2½ in. in diameter and a number of smaller knots scattered throughout the piece and all firm; will also admit of medium-sized live-limb knots.

Ex. 5. 1×6—16 No. 2 Common S. 1 S.—Will admit of large red or black knots scattered throughout the centre of the piece where they do not materially impair its strength.

Ex. 6. 1×4—16 No. 2 Common S. 1 S.—Graded practically the same as 1×6 No. 2 Common, admitting of the large knots not to exceed 2 in. scattered throughout the piece, but no large knots in the edge of the board.

No. 3 Common or Sheathing.—Will not only admit of all defects of the better grades, but will also admit of large loose knots and knot-holes and any amount of blue stain or pitch and a split extending not more than one-third length of board; but

no rot will be admitted in this grade except the unsound knots or red stain if the wood is quite firm. The boards of this grade must be of good thickness and full size, i.e., no pieces of split or broken boards will be allowed to go in this grade.

No. 4 Common or Culls.—The defects characterizing this grade are red- and black-rot pieces showing numerous large worm-holes or a large number of knot-holes or pieces that are extremely coarse-knotted or badly split.

Eastern Oregon White Pine Selects or Uppers will be divided into three grades of finish and shall be known as A or No. 1, B or No. 2, and C or No. 3.

A or No. 1 Finish shall be perfectly bright on the face side and free of knots or stain or pitch seams. The reverse side of the board may show one knot 1 in. in diameter or two knots less than 1 in. and small pitch seams, and may admit of a slight discoloration. Wider pieces will admit of relatively more defects on the reverse side.

B or No. 2 Finish will admit of more defects, larger and coarser knots, longer pitch seams and also some stain if not too pronounced. A 12-in. piece may show one knot $1\frac{1}{2}$ in. to 2 in. in diameter or two or three smaller knots; also a few small pitch seams. Light-blue sap stain may extend over not to exceed one-third of the face of the board where the knot defects are not so pronounced. In wider boards the defects may increase proportionately.

C or No. 3 Finish.—This is the lowest recognized grade of finish lumber and will admit of quite serious defects as long as the piece has the appearance of finish in the knotty type. A 12-in. piece may contain a large number of small knots and one or two very coarse knots or occasionally a knot-hole if board is otherwise fairly clear, or in the absence of knots the whole face of the piece may be blue, but where the piece is very blue no other defects are admissible. In this grade of finish the appearance of the face side only will be taken into consideration except that the reverse side must have a good bearing.

Flooring, Drop Siding, Rustic, and Ceiling, Select.—In grading this lumber the same rules will be used that govern the other selects except that the grade is determined from the face side only. In all except ceiling, and that only when it is specified as partition, then the grade shall be determined from the poorer side, but it should always be borne in mind that the reverse side should have a good bearing surface and nothing will be

allowed in A or B that would materially weaken the piece and only in a C when the defect may be removed by wasting six inches.

Common Flooring.—All flooring in the common grades shall be graded the same as wider pieces in the same grade, with the proper allowance for width.

Bevel Siding.—Care shall be taken in selecting this stock, which shall be free from knots in the edge, as in working the knots are liable to drop out, and a knot broken out in the thick edge gives the piece a rough appearance.

This siding shall be graded into four grades: No. 1 or A, No. 2 or B, No. 3 or C, No. 4 or D.

In A, or No. 1, the only defects admissible are a sound knot not to exceed ¼ in. in diameter or a very slight pitch pocket in a piece 12 feet or longer.

B, or No. 2, will admit of the defects in A or No. 1, together with other defects such as a small amount of stain, larger pitch pockets, or a little pitch or two or three small sound knots not exceeding ½ in. in diameter.

In C, or No. 3, the defects admissible are the same as B or No. 2, only more pronounced. It will admit of more discoloration and also of one or two loose knots or small knot-holes provided there would not be more than six inches of waste in the piece by cutting out these defects, and when the waste is allowed the balance of the piece must show a B face.

D, or No. 4, will admit of all the defects of the better grades and any amount of blue stain, or where the piece is badly discolored it shall be practically free of other defects. This grade is practically a cutting grade when not colored.

Factory Plank.—Grades described under this head are valued for cutting-up qualities only and should not be confounded, either in quality or value, with grades outlined in another part of this book for yard purposes.

Factory plank of all kinds shall be graded for the percentages of door cuttings that can be obtained.

Two grades of door cuttings only shall be recognized, and are to be known as No. 1 and No. 2 cuttings.

The only defect admissible in No. 1 cuttings is white sap.

The grade of No. 1 door cuttings must be free from all other defects.

The grade of No. 2 door cuttings will admit of one defect only in any one piece. This may be a small knot of sound character, not to exceed five-eighths of an inch in diameter, or the defect may be slightly stained sap which does not extend over more than one-half of the face of the piece on one side.

No. 1 Shop Common.—The sizes and grades of cuttings admissible in the grade of No. 1 Shop Common are as follows:

No. 1 Stiles in width 5½ or 6 in. and in length from 6 ft. 8 in. to 7 ft. 6 in.

No. 1 Rails 9 or 10 in. wide and from 2 ft. 4 in. to 3 ft. in length.

No. 1 Muntins 5½ in. wide and from 3 ft. 6 in. to 4 ft. in length.

Any number of pieces of either the stiles or rails mentioned above are admissible in the grade of No. 1 Shop Common; but only two muntins of the sizes mentioned above shall be considered, and one No. 2 door stile may also be considered, in securing the required percentage of cuttings in any given plank.

Each plank of No. 1 Shop Common shall contain not less than 50 per cent nor more than 70 per cent of door cuttings of the sizes and grades above mentioned.

No. 2 Shop Common.—The sizes admissible in No. 2 Shop Common are as follows:

Stiles in width 5½ in. or 6 in. and from 6 ft. 8 in. to 7 ft. 6 in. in length.

Rails 9 or 10 in. in width and from 2 ft. 4 in. to 3 ft. in length.

Top rails 5½ in. wide and from 2 ft. 4 in. to 3 ft. in length. Top rails must, however, be of No. 1 door-cutting quality.

Muntins 5½ in. wide and from 3 ft. 6 in. to 4 ft. in length.

Any number of cuttings of any one of the above sizes are admissible in the grade of No. 2 Shop Common.

Each piece of No. 2 Shop Common shall contain either one of the following: At least 25 per cent of No. 1 door cuttings, or not less than 40 per cent of all No. 2 door cuttings, or not less than 33⅓ per cent of No. 1 and No. 2 door cuttings combined.

No. 3 Shop Common, 1¼ in., 1½ in., and 2 in., will admit all below the grades described as No. 2 Shop Common, except such plank without cuttings as:

Show excessive rot.

Excessively pitch pieces.

Pieces stained on the greater part of both sides.

The type where there are no cuttings between knots and those knots are too unsound to be admitted in a cheap door.

A few small worm- or grub-holes, when not combined with blue sap or other serious defects, are admissible on one side of the piece only.

DOUGLAS FIR OR OREGON PINE.

GRADING RULES.

NOTES TO SURVEYORS.

Bureau of Grades and Inspection.—Surveyors at ports within the jurisdiction of the established Bureau of Grades and Inspection will receive their appointment from and be subject to the instructions of the properly designated officers of said Bureau, particularly as to an interpretation of the following rules:

At ports outside of said jurisdiction the surveyor shall be satisfactory to and subject to the mutual instructions of both buyer and seller as to any special conditions, but otherwise shall conform to the rules hereinafter noted and exercise his best judgment as to a correct interpretation thereof.

Sale Measure.—All intermediate (odd or fractional) lengths shall be measured as of the contents of the next longer length, unless otherwise especially instructed by the proper parties.

All lumber sawn less than 1″ in thickness shall be measured as of 1″ (i.e., at surface measure).

All rough lumber 1″ and over in thickness shall be measured at board-measure contents.

All worked lumber shall be measured at board-measure contents *before* working.

Sizes 4″ and under in thickness will be worked $\frac{1}{8}$″ less for each side surfaced. Sizes over 4″ in thickness will be worked $\frac{1}{4}$″ less for each side surfaced.

T. & G. S. 1 S. shall be worked $\frac{1}{8}$″ less in thickness and $\frac{5}{8}$″ narrower on face.

All sizes are subject to natural shrinkage, whether "green," partially or wholly seasoned, and in such cases the surveyor will make allowance for variations from above.

Recognized defects are knots, knot-holes, splits (either from seasoning, ring heart, or rough handling), shakes, wane, red

heart, rot, rotten streaks, worm-holes, pitch seams, pitch pockets, solid pitch, chipped grain, torn grain, loosened grain, seasoning checks, and black sap.

KNOTS shall be classified as pin, small, standard, and large as to size; round and spike as to form; and sound, loose, incased, pith, and rotten as to quality.

A pin knot is sound and not over $\frac{1}{2}''$ in diameter.

A small knot is sound and not over $1''$ in diameter.

A standard knot is sound and not over $1\frac{1}{2}''$ in diameter.

A large knot is sound and any size over $1\frac{1}{2}''$ in diameter.

A round knot may be oval or circular in form, and the mean or average diameter shall be considered in applying these rules.

A spike knot is one sawn in a lengthwise direction.

A sound knot is one solid across its face, as hard as the wood it is in, and so fixed by growth or position that it will retain its place in the piece.

A loose knot is one not held firmly in place by growth or position.

An incased knot is one surrounded wholly or in part by bark or pitch.

A pith knot is a small sound knot with a pith hole not more than $\frac{1}{4}''$ in the centre.

A rotten knot is one not as hard as the wood it is in.

PITCH.—Seams are openings between the grain of wood containing more or less pitch and shall be classified as large and small.

A large pitch seam is one $\frac{1}{8}''$ and over in open width and not over $8''$ in length.

A small pitch seam is one less than $\frac{1}{8}''$ in open width and not exceeding $4''$ in length.

A pitch pocket is a well-defined accumulation of pitch at one point of the piece.

A pitch seam or pocket showing open on both sides of the piece $\frac{1}{8}''$ or more in width shall be considered the equivalent of a knot-hole.

GRAIN.—Chipped grain consists of a part of the surface being chipped or broken out in small particles below the surface, but shall not be classed as torn grain.

Torn grain consists of a part of the wood being torn out in dressing, usually around knots or curly places.

Loosened grain consists of the point of one grain being torn loose from the next grain, noticeable on the heart side of a piece.

SAP.—Colored, blue or black.

Bright sap shall not be considered a defect unless the surveyor shall receive from the supervising inspector, or both buyer and seller, contrary instructions.

SUNDRIES.—Firm red heart shall not be considered a defect in any of the grades of commons.

Occasional variations in sawing, or occasional scant thickness, shall not be considered a defect when not rendering the piece unfitted for its probable use.

Imperfect manufacture in dressed stock, such as chipped grain, torn grain, loosened grain, broken knots, mismatching, or insufficient tongue or groove, will reduce the grade, according to whether such defects are slight or serious, in their effect upon the use of the piece.

Equivalent, in the application of these rules, means that the defects allowed, whether specified or not, are understood to be equivalent in damaging effect to those specially mentioned.

The grades of all regular stock shall be determined by the number, character, and position of defects visible in any piece. The enumerated defects permissible in any grade are intended to be descriptive of the coarsest piece such grade may contain hereunder; the average quality of the grade should be about midway between such piece and the coarsest piece allowed in the next higher grade.

DOUGLAS FIR.

Grades shall be known and designated as follows:

ROUGH AND WORKED COMMONS.—"Merchantable," "Seconds," "Refuse."

ROUGH UPPERS.—"Clear," "Select."

Car Stock—"No. 1," "No. 2."

Ship Stuff—"No. 1," "No. 2."

WORKED UPPERS.—D. & M. Flooring—"No. 1," "No. 2," "No. 3."

Stepping—"No. 1," "No. 2," "No. 3."

Rustic—"No. 1," "No. 2," "No. 3."

Ceiling—"No. 1," "No. 2," "No. 3."

ROUGH COMMONS.—*Merchantable.*—This grade shall consist of lengths 10′ and over (except shorter lengths be ordered) of sound, strong lumber, free from loose or rotten knots, knot-holes, splits, shakes, wane, rot, pitch seams (open on both sides of the piece), or other defects that materially impair the

strength of the piece; well manufactured and suitable for good substantial construction purposes, or the purpose for which it is intended. Will allow:

Occasional variations in sawing, or occasional scant thicknesses.

Sound large knots.

Large pitch seams.

Bright or colored sap on corners one-third the width and one-half the thickness.

Firm red heart.

Recognized defects in all cases to be considered in connection with size of piece and its quality otherwise.

Bill Stuff shall consist of sizes ordered for specific construction and not intended for "Yard Stock," and must be inspected with the view of its adaptability to the uses intended, and unless manifestly unfit therefor shall be surveyed under this grade, except the order be for a higher grade.

Seconds.—This grade shall consist of lengths 10′ and over (except shorter lengths be ordered) having any of the recognized defects which exclude it from grading as Merchantable. Will allow:

Recognized defects which render it unfit for good substantial construction purposes but suitable for an inferior class of work.

Refuse.—This grade shall consist only of commons absolutely unfit for any other use than firewood.

ROUGH UPPERS.—*Selects.*—Shall be sound, strong lumber, and in flooring, ceiling, and finish stock of good grain, well manufactured. Will allow:

In sizes under 6″×6″:

Pin knots, bright sap on corners one-quarter the width and one-half the thickness, and small pitch seams. Not more than two such defects in for each 10 linear feet.

In sizes 6″×6″ and over:

Small and standard knots varying in diameter according to size of piece.

Bright sap on corners not to exceed 3″ on both faces and edges.

Large pitch seams.

Recognized defects to be considered in all cases in connection with size of piece and its general quality.

Clears.—Flooring, ceiling, and finish stock shall be sound, close grain, well sawn, and on one side and two edges free from defects impairing its use for probable purposes intended.

Edge grain in widths 12″ and wider shall be so graded if showing grain on edge within an angle of 45 degrees for at least three-fourths of width and otherwise free from defects on one face and two edges.

Slash grain (nearly parallel to surface) shall be otherwise free from recognized defects on one face and two edges.

Other lumber in this grade shall be uniformly sawn and generally free from recognized defects. Will allow—

In dimensions containing 24″ or less to the linear foot:

Bright sap when not exceeding one-quarter the width, thickness, or length.

Small pitch seams when not extending through the piece.

In dimensions 3″ to 6″ thick and over 8″ to 12″ wide:

Pin knots when on one side and lower half of edges.

Bright sap not exceeding one-fourth the face or edges, or one-third the length.

Small pitch seams when not extending through the piece.

In dimensions larger than above:

Small knots, according to size of piece, when on one face and lower half of edges, leaving one face and upper half of edges clear.

Bright sap on corners not exceeding 3″ on face and edges, or one-half the length.

Large pitch seams when not extending through the piece.

Ship Stuff.—All lumber for this purpose shall be strong, of live wood, and close grain.

No. 1 *Plank.*—Includes outboard planking, garboards, wales, clamps, rails, and lumber for similar purposes; if worked, to be fairly smooth. Will allow:

Small tight, hard knots when not on corners or calking seam.

Bright sap on face side edges not exceeding one-quarter the width or thickness.

Small pitch seams not extending through the piece.

Said defects to be considered in connection with size of piece and its quality otherwise.

No. 1 *Decking.*—Shall be uniformly sawn, close grain, free from recognized defects on one face and both edges, and if

worked to be of uniform size and fairly smooth. Flat sizes shall show edge grain on broad face, and both square and flat sizes be free from recognized defects on edge grain face. Will allow:

Pin knots on under side and lower part of calking edges.

Bright sap on face side edges not exceeding one-eighth the width and one-fourth the thickness.

No. 2 Plank and Decking.—This grade shall include all of above material not suited for grading as No. 1 hereunder, but in quality shall be equal to the grade of Select.

Car Stock.—Lumber in this grade shall be strong, of fine grain, and uniformly sawn. Sizes 2″ thick and less and 12″ and less wide shall be practically clear, free from all recognized defects that would impair it for its intended use. Will allow in dimensions over 2″ thick and 12″ wide:

Small knots, according to size of piece.

Bright sap in limited amount, according to size of piece.

Small pitch seams.

Said defects to be considered in connection with size of piece and its quality otherwise.

No. 2.—This grade shall include material impaired by recognized defects from grading as No. 1, but generally conforming to the grade of "Selects."

Car Siding and Roofing.—To be graded under rules for D. & M. ceiling.

WORKED UPPERS.—*D. & M. Flooring. No.* 1.—This grade shall consist of lengths 10′ and up (except shorter lengths be ordered), edge grain on face for three-quarters of width; of sound, close grain lumber, and free from recognized defects on face and edges; well worked and conform generally to grade of Clears. Will allow:

One pin knot in each piece.

Bright sap when not extending over one-quarter face and length.

Only one such defect allowed in any one piece.

No. 2.—This grade shall consist of edge or slash grain of lengths 10′ and up (except shorter lengths when ordered), well worked and conform generally to the grade of Selects. Will allow:

Small knots if not appearing on edges.

Bright sap when not extending over one-half the face and length.

Small pitch seams.

Chipped grain.

Said defects to be considered in connection with length of piece and its quality otherwise. Not more than two such defects to each 12 linear feet.

No. 3.—This grade shall consist of lengths 6′ and up regardless of grain and conform generally to grade of Merchantable.

Stepping.—This material shall consist of lengths 10′ and over (except shorter lengths be ordered), and defects allowed shall be considered with regard to length of piece.

No. 1.—This grade shall conform generally to grade of Clears, be worked smooth on one side, shall show edge grain on face to extent of not less than three-fourths of width, and free from defects on face and one edge.

No. 2.—This grade shall show edge grain on face to extent of not less than one-half the width and conform generally to grade of "Selects." Will allow:

Pin knots on one face or one edge.

Bright sap when not extending over one-quarter the width.

Small pitch seams.

Chipped grain and other recognized defects impairing it from grading as No. 1.

No. 3.—This grade shall be regardless of grain and conform generally to grade of Merchantable.

Rustic Siding and Ceiling. No. 1.—Shall consist of lengths 10′ and up (except shorter lengths be ordered), sound lumber, regardless of grain, free from recognized defects on face and edges, well worked, and conform generally to grade of "Clears." Will allow:

One pin knot.

Or bright sap not extending over one-quarter width or length of piece.

Only one such defect allowed in any one piece.

No. 2.—This grade shall conform generally to grade of "Selects." Will allow:

Small knots if not appearing on edges.

Bright sap when not extending over one-half the face and length.

Small pitch seams if not extending through the piece.

Chipped grain.

Said defects to be considered in connection with size and length of piece.

No. 3.—Shall conform generally to grade of Merchantable.

CALIFORNIA REDWOOD.

Clear Redwood.—*No.* 1. Shall be good and sound, clear of knots, splits, sap and shakes, and well manufactured to standard thickness. Will allow:

Small birdseye.

Slash-grained sawing.

No. 2. Shall be inferior in quality to No. 1. Will allow:

Small sound knots and pin knots, sap on end and edge not exceeding 4 per cent of area.

Slight roughness in milling.

Tank, Panel, and Casing Stock.—Shall be good and sound clear of knots, splits, sap, and shakes, and well manufactured.

Sap Clear.—This grade shall conform generally to No. 1 and No. 2 Clear, except that it shall contain sap in excess of 4 per cent of the area. Will allow:

Discoloration of sap.

Flooring, Ceiling, and Rustic Stock.—No. 1. Shall be the grade of No. 1 clear. Will allow:

Slash-grained sawing that will probably not rough up in working.

No. 2. Shall conform to the grade of No. 2 clear.

Standard Grade, Rustic Stock.—Will allow:

3 or 4 sound standard ($1\frac{1}{4}''$ diameter) knots.

1 or 2 sound knots not to exceed $2''$ in diameter.

Sap with small knots.

Poor machining, which would make it unfit for No. 1 and No. 2 clear.

Half-inch Lumber.—Shall be graded under the same rules as inch lumber of the same quality.

Grades, Common.—*No.* 1. This grade shall consist of sound, strong lumber, free from rot, large shake and large, loose knots. It shall be well manufactured and suitable for good, substantial construction purposes. Will allow:

Occasional variations in widths and thickness.

Knots, weather check, and small shake that do not materially impair its strength.

Sap not to exceed 4 per cent of the area of outside surfaces.

No. 2. This grade shall consist of lumber having any of the recognized defects which exclude it from the No. 1 grade. Will allow:

Sap, loose and rotten knots and shakes; also splits not extending over one-fourth the length of the piece.

Recognized defects which render it unfit for good, substantial construction purposes but suitable for an inferior class of work.

No. 3. This grade shall consist of anything that is not good enough to go into No. 2 grade, but which can be used for any purpose as lumber.

DIFFERENT KINDS OF WOOD AND WHERE FOUND.

Name.	Where Found.
Acacia	Warm climates.
Alder	Europe, etc.
Almond	South of Europe.
Amboine	Africa.
Apple	Europe, America.
Apple (crab)	East. United States.
Arbor-vitæ	Temperate climates.
Ash	Britain, etc.
" black	East. United States.
" blue	" " "
" white	" " "
Bamboo	China and India.
Barwood	Africa.
Basswood	East. United States.
Beech	" " "
Birch	Europe, America.
Bite	India.
Black Botany Bay wood	Australia.
Blue-gum	"
Bog-oak	England, Ireland.
Boxwood	Southern and western Europe.
Brazil wood	Brazil.
Buckeye	Tennessee and North.
Bullet-tree	Jamaica.
Buttonwood	(See Sycamore.)
Calamander	Ceylon.
Camphor	Warm climates.
Camwood	Africa.
Canary-wood	Brazil.
Caugica-wood	"
Catalpa	East. United States.
Cedar, bastard	Southern California.
" red	East. United States.
" yellow	Utah to Pacific Coast.
East India blackwood	East Indies.
Ebony	Ceylon, Africa, India.
Elder	Jamaica.
Elm	Europe.
" red	East. United States.
" white	" " "
Fir, red silver	Sierra Nevada Mts.
" Scotch	Europe.
" silver	California.
Fustic	North and South America.
Greenheart	Guiana, Trinidad.
Gum, black and red	East. United States.
Hawthorn	Europe, etc.
Hazel	" "
Hemlock (spruce)	North America.
Hickory	America.
Holly	Europe, Southeastern United States.
Hoonsay	India.
Ironwood	East. United States.
" red	Jamaica.
Jackwood	Asia, Ceylon.
Juniper	(See Cedar.)
Kiaboca	East Indies.
Kingwood	Brazil.
Laburnum	Europe.
Lancewood	South America.
" black	Jamaica.
Larch	Europe.
" Western	Oregon.
Laurel, mountain	Penn. and South.
Leopard-wood	Central America.

DIFFERENT KINDS OF WOOD AND WHERE FOUND—(*Continued*).

Name.	Where Found.
Cedar, Spanish	West Indies and South America.
" Western	Utah to Oregon.
" white	United States.
" West India	West Indies.
Cherry	Europe, America.
Cherry, wild, black	East. United States.
Cherry-tree	Australia.
Chestnut	America, Europe.
Cocoa-wood	West Indies.
Coquilla-nut	Brazil.
Cork-oak	Southwest Europe.
Cottonwood	West. United States.
Cowdi-pine	Temperate climates.
Cypress	So. United States.
"	New Zealand.
Deodar	India.
Dogwood	Tasmania, Jamaica, and East. United States.
Mustaiba	Brazil.
Myrtle	Southern Europe, Tasmania.
Nellec	India.
Nettle-tree	South of Europe.
Norfolk Island pine	Norfork Island.
Norway spruce	Norway.
Novaladdi	India.
Oak	Europe, etc.
" African	Africa.
" black	East. United States.
" white	" " "
" red	" " "
" chestnut	" " "
Olive	Europe, Syria, California.
Osage orange	Arkansas and South.
Osiers	Europe.
Oyster Bay wood	Tasmania.
Paddle-wood	Guiana.
Palm	Tropical climates.
Partridge-wood	West Indies, South America.
Pine	Europe and Asia.
" yellow	North America.
" red	" "
" white	" "
" spruce	" "
Plane	North America, Asia, Britain.
Plum	Britain, etc.
Poon	West Indies.
Poplar	Europe, Asia.
"	East. United States.
Porcupine-wo'd	Tropical climates.
Prima Vera	Mexico.
Purpleheart	Brazil.
Quassia	Tropical climates.
Rattans	" "
Red sanders	India.
Redwood	California.

Name.	Where Found.
Lignum-vitæ	West Indies and Florida.
Lime	Europe.
Linn	East. United States.
Locust	West Indies.
"	East of Mississippissi River.
Mahogany	Central America and Cuba.
" mountain	Rocky Mountains.
" white	(See Prima Vera.)
Mangrove	Tropics.
Maple, black	East. United States.
" red	" " "
" sugar	" " "
Mountain-ash	Australia, Britain, etc.
Mulberry	Europe and China.
" red	East. United States.
Muskwood	Tasmania, New South Wales.
Rhododendron	Himalaya.
Rosewood	Tasmania.
Sandalwood	India.
Sapan-wood	"
Sassafras	America, Tasmania.
Satinwood	East Indies.
Saul	" "
Scotch fir	Scotland.
Service-tree	East. United States.
She-oak	Tasmania.
Silverwood	Cape of Good Hope.
Snakewood	West Indies.
Spindle-tree	Britain, etc.
Spruce, black	Sierra Nevada Mts.
" Engleman's	Rocky Mountains.
Stringy-bark	Australia.
Sycamore	Temperate climates.
"	East. United States.
" (fig)	Egypt.
Tamarack (American larch)	Northern and Northeastern United States.
Teak, African	Africa.
" Indian	India.
Thorn	East. United States.
Toonwood	India.
Toqua	Himalaya.
Tulip-wood	Australia.
Vegetable ivory	Central America.
Walnut, black	East. United States.
White (butternut)	" " "
" English	Europe.
" French	Persia, Asia Minor.
Whitewood	New South Wales.
Willow	Europe, America.
Yacca-wood	Jamaica.
Yew-wood	Britain, California, Oregon.
Zebray	Brazil.

STRENGTH, WEIGHT, ETC., OF VARIOUS WOODS.

Name.	Strength per Sq. In. in Lbs.		Moduli of Elasticity.	Relative Hardn'ss Shell-bark Hickory being 1000.	Weight per Cubic Foot.	Specific Gravity.
	Tensile.	Crushing in Direction of Grain.				
Acacia-wood	....	....	....	....	46.5	.750
Alder-wood	....	6,150	....	....	50	.800
Apple-wood	....	....	....	700	49	.793
Ash (white)	17,000	8,600	....	775	40.77	.610
Ash (brown)	11,000	....	....	....	38.96	.623
Boxwood	18,000	10,000	....	....	62	.990
Birch	15,000	8,000	....	630	35.44	.567
Beech	11,500	9,000	....	660	40.42	.650
Butternut	9,000	6,000	....	440	23.50	.376
Cherry	....	....	....	550	44.70	.715
Chestnut	10,500	5,000	1,000,000	520	41.25	.660
Cork	....	....	....	....	15	.240
Cedar (white)	11,400	6,500	700,000	540	37.25	.596
Cedar (red)	9,000	6,000	....	....	35	.560
Cypress	5,000	6,000	900,000	....	27.60	.441
Dogwood	....	....	....	750	47.25	.750
Ebony	....	....	....	....	86.16	1.331
Elm	13,000	8,000	....	580	42	.671
Fir	10,000	7,000	1,200,000	....	32	.512
Gum	17,000	7,000	....	....	52.69	.843
Hazel	....	....	....	720	53.75	.860
Holly	....	....	....	....	47.50	.760
Hickory (pignut)	15,000	9,000	....	950	49.50	.792
Hickory (shell-bark)	18,000	10,000	....	1000	43.12	.690
Hemlock	8,740	5,400	900,000	....	23.00	.368
Hackmatack	....	....	....	....	37.00	.592
Juniper	....	....	....	....	35.37	.566
Lancewood	....	....	....	....	45	.720
Larch	9,500	....	....	....	34.55	.552
Lignum-vitæ	12,000	9,000	....	....	83.31	1.333
Logwood	....	....	....	....	57.06	.913
Locust	20,000	11,720	....	....	45.50	.728
Mahogany	12,000	6,000	....	....	55.75	.829
Maple (hard)	10,000	9,000	....	550	46.87	.750
Maple (white)	10,000	7,000	....	....	36	.576
Oak (white)	16,000	6,000	1.100,000	850	53.75	.860
Oak (red or black)	10,000	8,000	....	700	40.75	.652
Pear	9,800	....	....	....	47	.752
Plum	....	....	....	....	49.06	.785
Poplar	7,000	5,000	....	510	23.99	.383
Pine (white)	7,000	5,000	1,000,000	300	30	.480
Pine (Norway)	8,300	7,000	1,200,000	....	33.25	.532
Pine (yellow)	16,000	5,500	1,200,000	540	38.40	.612
Pine (yellow long-leaf)	20,000	9,000	1,700,000	....	43.62	.698
Pine (Oregon)	13,800	7,000	1,400,000	....	34	.544
Rosewood	....	....	....	....	45.50	.728
Redwood (Cal.)	8,000	2,500	7,00000	....	26.23	.419
Satinwood	....	....	....	....	55.31	.885
Spruce (white)	14,000	6,500	1,200,000	....	31.25	.500
Tamarack	....	....	....	....	23.93	.383
Walnut	10,000	8,000	....	650	41.93	.671
Willow	12,000	....	....	....	33.40	.535

Plumbing.—In this part of the work the superintendent must see that the materials are all as specified; he should see that the pipe used is of the right size and weight, and that all fixtures are in perfect condition. He should provide himself with a catalogue of the various fixtures to be used so he will know if the proper fixtures are provided.

In running the sewers and soil-pipes he must see that a proper fall is given, which should not be less than that given in the following table:

Diameter of pipe, inches. . . .	2	3	4	5	6	7	8	9	10
Length to 1 foot of fall, feet.	20	30	40	50	60	70	80	90	100

A small pipe should have a greater fall than a large one on account of the friction being greater compared with the amount of water used.

All turns and connections should be made with Y branches and $\frac{1}{8}$ bends. If the joints are made with lead the superintendent should see that they are made with one pouring of the lead and calked tight.

When earthenware pipe is used for sewers they must be examined for cracks, and to see if the bowl is in perfect condition care must be taken in making the cement joints so as to leave the inside of the pipes smooth and level; as the pipes are laid the inside should be wiped out so as to wipe out any surplus cement on the inside. Fig. 227, *A*, shows how pipes of

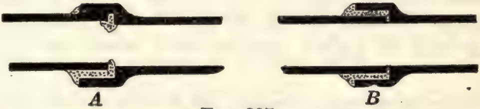


FIG. 227.

this kind are often laid, while Fig. 227, *B*, shows how they should be laid.

After all sewers, soil- and vent-pipes are in place they should be tested by plugging the bottom or main outlet and filling all the pipes to the roof level; this test should remain on for at least six hours, after which all pipes and joints should be thoroughly examined for leaks.

Soil- and vent-pipes should be securely fastened to the walls and the vertical runs of pipe should set on a firm footing. Lead pipe should be examined before using as to weight and thick-

ness, and as to quality and condition of the pipe. By rough handling of the coil of pipe in many cases the pipe is flattened so as to render it unfit for use.

In laying water-pipes, or in fact pipes of any kind, they should be laid so that they will drain themselves, and in no case should any pipe be placed so as to cause a seal or trap in the pipe.

Stopcocks should be placed on all water lines where they can be got at conveniently, controlling each fixture or set of fixtures.

After all fixtures are in place the pipe and fixtures should be tested with smoke, which is applied at the main outlet by burning rags or waste saturated with oil, and forcing the smoke up the pipes; after the pipes are filled with smoke the whole system should be gone over and any joint or connection where there is an odor of smoke should be examined, as any smell of smoke is an indication of a leak. This test is mainly for the connections of the fixtures, as the pipes have already been tested by the water test.

The water system should be tested by hydraulic pressure.

The following rules regarding plumbing are taken from the Philadelphia Building Code:

Main drain to be connected with street sewer.

When private sewer is necessary, plans must be approved by Board of Health.

Joint drain not to be laid in cellars.

Rule 10. The main drain of every house or building shall be separately and independently connected with the street sewer, where one is provided; and where there is no sewer in the street, and it is necessary to construct a private sewer to connect with one on an adjacent street, such plans may be used as may be approved by the Board of Health; but in no case shall a joint drain be laid in cellars parallel with street or alley.

Material to be used in underground house-drains.

All house-drains laid beneath the ground inside of buildings or beneath the cellar floor shall be of plain, extra-heavy cast-iron pipe, with well leaded and calked joints, or of wrought iron, with screw joints made with a paste of red lead and treated to prevent corrosion.

Material to be used in other drain- or soil-pipes.

All other drains or soil-pipes connected with the main drain, or where the main drain pipe is above the cellar floor, shall be of plain cast-iron pipe, or of wrought-iron pipe with screw joints made with a paste of red lead and treated to prevent corrosion.

Outside of the buildings, where the soil is of sufficient solidity for a proper foundation cylindrical terra-cotta pipes of the best quality, free from flaws, splits, or cracks, perfectly burned, and well glazed over the entire inner and outer surfaces may be used, laid on a smooth bottom, with a special groove cut in the bottom of trench for each hub (in order to give the pipe a solid bearing on its entire length) and the soil well rammed on each side of the pipe. The spigot and hub ends shall be concentric.

Terra-cotta drain-pipes may be used outside of buildings under certain conditions.

The space between the hub and pipe shall be thoroughly filled with the best cement mortar, made of equal parts of the best American natural cement and bar sand thoroughly mixed dry, and water enough afterward added to give it proper consistency. The cement must be mixed in small quantities at a time and used as soon as made. The joints must be carefully wiped and pointed, and all mortar that may be left inside thoroughly cleaned out and the pipe left clean and smooth throughout, for which purpose a swab shall be used.

Space between hub and pipe to be filled with cement mortar.

Joints to be properly finished.

No tempered-up cement shall be used. A straight-edge shall be used, and the different sections shall be laid in perfect line on the bottom and sides; but in no case shall terra-cotta pipes be permitted within five (5) feet of any foundation-wall, or for extension to connect with rain-water conductors, surface or air inlets.

Quality of cement.

Terra-cotta pipes not to be within 5 feet of foundation-wall, nor used for extensions.

Note.—After the test has been approved by the inspector, iron drain- or soil-pipes may be tar-coated. But in no case shall any coating be applied to cast-iron soil- or drain-pipes until test has been applied and approved by the inspector.

Coating of pipes not to be done until after approval by inspector.

Rule 11. The house-drain shall be not less than four (4) inches, nor more than ten (10) inches in diameter, and the fall shall not be less than one-half (½) an inch to the foot, unless by special permission of the Board of Health; it shall be laid in a trench cut at a uniform grade, or it may be constructed along the foundation-

Construction of house-drains.

walls above the cellar floor, resting on nine (9) inch brick piers laid in cement mortar (said piers to be not more than seven (7) feet apart) and securely fastened to said walls; no tests shall be made by the inspector until said pipes are secured as above described.

Arrangement of house-drains.

Rule. 12. The arrangement of soil- and waste-pipes shall be as direct as possible. All changes in direction on horizontal pipes shall be made with Y branches, one-sixteenth ($\frac{1}{16}$) or one-eighth ($\frac{1}{8}$) bends.

Location of main trap of house-drain.

Rule 13. The house-drain shall be provided with a horizontal trap, placed immediately inside the cellar wall nearest to the sewer, or at the curb. The trap shall have a hand-hole, for convenience in cleaning, the cover of which shall be properly fitted and the joints made air-tight.

Main trap to have a hand-hole.

Note.—If the trap and the main drain is placed inside of the cellar wall, there shall be no clear-out between the water seal of the trap and the sewer.

Location of fresh-air inlets in drains.

Rule 14. There shall be an inlet for fresh air entering the drain just inside the water seal of the main trap, and also at the rear of the system, when the vertical line of soil-pipe is located in the central part of the building and the main fresh-air inlet is deemed insufficient to ventilate the entire system. Said inlets shall be at least four (4) inches in diameter, leading to the outer air and opening at any convenient place, with an accessible clean-out. Where air inlets are located off the footway, on grass plots, lawns, etc., they shall extend not less than six (6) nor more than fifteen (15) inches above the surface of the ground and be protected by a cowl securely fastened with bolts.

Relieving arch required when drain-pipe passes through a new foundation-wall.

Rule 15. Where the drain passes through a new foundation-wall a relieving arch shall be built over it with a two (2) inch clearance on either side.

Rule 16. Every vertical soil-pipe shall extend at least two (2) feet above the highest part of the

building or contiguous property, and shall be of undiminished size, with the outlet uncovered except with a wire guard. Such soil-pipe shall not open near a window nor an air-shaft ventilating living-rooms.

Construction of vertical soil- or waste-pipes.

Rule 17. Every branch or horizontal line of soil-pipe to which a group of two (2) or more water-closets is to be connected, and every branch line of horizontal soil-pipe eight (8) feet or more in length, to which a water-closet is to be connected, shall be ventilated, either by extending said soil-pipe, undiminished in size, to at least two (2) feet above the highest part of the building or contiguous property, or by extending said soil-pipe and connecting it with the main soil-pipe above the highest fixture, or by a ventilating pipe connected to the crown of each water-closet trap, not less than two (2) inches in diameter, which shall be increased one-half ($\frac{1}{2}$) an inch in diameter for every fifteen (15) feet in length, and connected to a special air-pipe, which shall not be less than four (4) inches in diameter, or by connecting said ventilating pipe with the main soil-pipe above the highest fixture.

Branch or horizontal soil-pipes to which water-closets are connected to be ventilated; manner of such ventilation.

Rule 18. Where a separate line of waste-pipes is used, not connected with sewer-pipes, it shall also be carried two (2) feet above the highest part of the building or contiguous property, unless otherwise permitted by the Board of Health. But in no case shall a waste-pipe connect with a rain-water conductor.

Construction of waste-pipes not connected with sewer-pipes.

Waste-pipe not to connect with rain-water conductor.

Rule 19. There shall be no traps, caps, or cowls on soil- and waste-pipes which will interfere with the system of ventilation.

No obstruction to ventilation to be placed on soil or waste-pipes.

Rule 20. All soil-, waste-, anti-siphon pipes and traps inside of new buildings, and of the new work in old buildings, and also of the entire system when alterations are made in old buildings, and the owner or agent of said building or buildings shall have contracted to have the entire drainage system tested, shall have openings stopped and a test of not less than three (3) pounds atmospheric pressure to the square inch applied.

Test of not less than 3 pounds pressure per square inch to be applied to drain-pipes and traps.

Rule 21. The drain-, soil-, and waste-pipes, and the traps, shall, if practicable, be exposed to view for ready inspection at all times, and for convenience in repairing. When placed within walls or partitions and not exposed to view, or not covered with woodwork fastened with screws so as to be readily removed, or when not easily accessible, extra-heavy pipes shall be used at the discretion of the Board of Health.

Drain-pipes and traps to be easily accessible when practicable.

When drain-pipes and traps are not easily accessible, heavy pipe to be used.

Rule 22. No drainage work shall be covered or concealed in any way until after it has been examined and approved by a house-drainage inspector, and notice must be sent to the Board of Health, in writing, when the work is sufficiently advanced for such inspection; and immediately on the completion of the work application must be made for final inspection. The failure on the part of a master plumber to make said application for final inspection, or the violation of any of the rules of the Board of Health in the construction of any drainage work, and failure to correct the fault after notification, will be deemed sufficient cause to place his name on the delinquent list until he has complied with said rules and regulations. Any attempt on the part of a master plumber to construct or alter a system of drainage during the time his name appears on said delinquent list will subject him to criminal prosecution.

Drainage work not to be covered or concealed until inspected.

Notice to Board of Health.

Final inspection.

Name of master plumber to be placed on delinquent list for violation of rules of Board of Health.

Criminal prosecution in case a delinquent shall do any drainage work.

Rule 23. All drain and anti-siphon pipes of cast iron shall be sound, free from holes, and of a uniform thickness, and shall conform to the following relative weights:

Quality and weight of drain- and soil-pipes.

Standard.			Extra Heavy.		
In.		Lbs.	In.		Lbs.
2	pipe,	4 per foot.	2	pipe,	$5\frac{1}{2}$ per foot.
3	"	6 "	3	"	$9\frac{1}{2}$ "
4	"	9 "	4	"	13 "
5	"	12 "	5	"	17 "
6	"	15 "	6	"	20 "
7	"	20 "	7	"	27 "
8	"	25 "	8	"	$33\frac{1}{2}$ "
10	"	35 "	10	"	45 "
12	"	45 "	12	"	54 "

Rule 24. All drain and anti-siphon cast-iron pipes shall have the weight per foot and the name of the manufacturer cast on the exterior surface, directly back of the hub of each section, in characters not less than one-half ($\frac{1}{2}$) inch in length.

Name of manufacturer and weight per foot to be cast on drain- and soil-pipes.

Rule 25. Lead waste-pipes may be used for horizontal lines that are two (2) inches or less in diameter, and shall have not less than the following prescribed weights:

When lead waste-pipes may be used.

1	inch pipe,	2 lbs.	0 oz.	
$1\frac{1}{4}$	" "	2 "	8 "	
$1\frac{1}{2}$	" "	3 "	8 "	
2	" "	4 "	0 "	

Weight of lead pipes.

Rule 26. Lead bends or traps for water-closets shall not be less than one-eighth ($\frac{1}{8}$) of an inch in thickness.

Thickness of lead bends or traps for water-closets.

Rule 27. Waste-pipes from wash-basins, sinks, and bath-tubs shall not be less than one and one-quarter ($1\frac{1}{4}$) inches in diameter, and wash-tray waste-pipes not less than one and one-half ($1\frac{1}{2}$) inches in diameter.

Diameter of water-pipes from wash-basins, sinks, bath-tubs, and wash-trays.

Rule 28. All joints in cast-iron drain-, soil-, and waste-pipes shall be so calked with oakum and lead, or with cement made of iron filings and salammoniac, as to make them gas-tight.

Joints in cast-iron drain-pipes to be calked.

Rule 29. All connections of lead with iron pipe shall be made with a brass ferrule not less than one-eighth ($\frac{1}{8}$) of an inch in thickness, put in the hub of the iron pipe and calked in with lead, except in cases of iron water-closet traps or old work, when drilling and tapping is permitted. The lead pipe shall be attached to the ferrule by a wiped solder joint.

Connections of lead with iron pipe to be made with a brass ferrule; how connection to be made.

Rule 30. All connections of lead pipe shall be by wiped solder joints.

Connections of lead pipe to be by solder joints.

Rule 31. Every water-closet, sink, basin, wash-tray, bath, and every tub or set of tubs, shall be separately and effectually trapped.

Water-closets, sinks, etc., to be separately trapped.

Rule 32. The trap must be placed as near the fixture as practicable. All waste-pipes shall be provided with strong metallic strainers. All

Location of traps.

Strainers.

drains from hydrants shall be trapped and in a manner accessible for cleaning out.

Drains from hydrants.

Rule 33. Traps of fixtures shall be protected from siphonage. All anti-siphon pipes shall be carried up and through the roof or connected with the main soil-pipes above the highest fixture.

Traps to be protected from siphonage.

Rule 34. Every anti-siphon pipe shall be of lead, of galvanized gas-pipe, or of plain cast-iron pipe. Where these pipes go through the roof they shall extend two (2) feet above the highest part of the building or contiguous property; they may be combined by branching together those which serve several traps. These pipes where not vertical must always be a continuous slope, to avoid collecting water by condensation.

Construction of anti-siphon pipes.

Material to be used in anti-siphon pipes.

Construction of same.

Rule 35. All drip- or overflow-pipes from safes under wash-basins, baths, urinals, water-closets, or other fixtures shall be by a special pipe run to an open sink outside the house or some conspicuous point; and in no case shall any such pipe be connected with a soil-, drain-, or waste-pipe.

Construction of drip- or overflow-pipes.

Rule 36. No waste-pipe from a refrigerator or other receptacle in which provisions are stored shall be connected with any drain-, soil-, or other waste-pipe. Such waste-pipes shall be so arranged as to admit of frequent flushing, and shall be as short as possible.

Waste-pipe from refrigerator, etc., not to be connected with any drain-pipe.

Rule 37. The overflow-pipes from tanks and the waste-pipes from refrigerators shall discharge into an open fixture properly trapped.

Discharge of overflow from tanks and refrigerator waste-pipes.

Rule 38. All water-closets within buildings shall be supplied with water from special tanks or cistern which shall hold not less than eight (8) gallons of water when up to the level of the overflow-pipe for each closet supplied, excepting automatic or siphon tanks, which shall hold not less than five (5) gallons of water for each closet supplied; the water in said tanks shall not be used for any other purpose. The flushing-pipe of all tanks shall not be less than one and one-quarter ($1\frac{1}{4}$) inches in diameter.

Water-closets to be supplied with water from flushing-tanks.

Capacity of such tanks.

Size of flushing-pipe.

Rule 39. No closet, except those placed in the yard, shall be supplied directly from the supply pipes.

Water-closets not to be supplied directly from main.

Rule 40. A group of closets may be supplied from one tank, but water-closets on different floors shall not be flushed from one tank.

Supplying different closets from same tank.

Rule 41. Water-closets, when placed in the yard, shall be so arranged as to be conveniently and adequately flushed, and their water-supply pipes and traps shall be protected from freezing by placing them in a hopper-pit, at least three and one-half ($3\frac{1}{2}$) feet below the surface of the ground, the walls of which shall be of brick or stone laid in cement mortar. The water-pipe from the hopper stopcock shall be conveyed to the drain through a three-eighths ($\frac{3}{8}$) inch pipe, properly connected.

Yard water-closets to be adequately flushed.

Protection of supply pipes to same from freezing.

Rule 42. The inclosure of the yard water-closet shall be ventilated by slatted openings, and there shall be a trap-door in the floor of sufficient size for access to the hopper-pit.

Inclosure of yard water-closets to be ventilated and have trap-door in floor.

Rule 43. Water-closets must not be located in the sleeping-apartments of any building, nor in any room or apartment which has not direct communication with the external air either by a window or an air-shaft having an area to the open air of at least four (4) square feet.

Water-closets not to be located in sleeping-apartments nor in apartment without communication with external air.

Rule 44. The containers of all water-closets shall be supplied with fresh air and properly ventilated, as approved by the Board of Health.

Containers of water-closets to be ventilated.

Rule 45. All water-closets within a building using lead connections shall have a cast-brass flange not less than three-sixteenths ($\frac{3}{16}$) of an inch in thickness (fitted with a pure-rubber gasket of sufficient thickness to insure a tight joint) bolted to the closet.

Lead connections to water-closets within a building.

Rule 46. Where latrines are used for schools they shall be of iron, properly supplied with water, and located in the yard at least twenty (20) feet from the building when practicable.

Construction of latrines for schools.

Rule 47. Rain-water conductors shall be connected with the house-drain or sewer and be

Rain-water conductors to be connected

provided with a trap the seal of which shall be not less than five (5) inches. Said trap shall have a hand-hole for convenience in cleaning, the cover of which shall be made air-tight.

with house-drain or sewer and provided with trap; trap to have hand-hole.

Rain conductors shall not be connected outside of the main trap, nor used as soil-, waste-, or vent-pipes; nor shall any soil-, waste-, or air-pipe be used as a rain conductor, and if placed within a building shall be of cast iron with leaded joints.

Rain conductors not to be connected outside of main traps, nor used as soil- or waste-pipes.

Rule 48. No steam exhaust or waste from steam-pipes shall be connected with any house-drain or soil-pipe.

Steam-exhaust pipes not to be connected with drain-pipes.

Rule 49. No privy vault or cesspool for sewage shall hereafter be constructed in any part of the city where a sewer is at all accessible.

Privy-vault or cesspool not to be constructed where a sewer is accessible.

Rule 50. No connection from any cesspool or privy-well shall be made with any sewer, nor shall any water-closet or house-drainage empty into a cesspool or privy-well.

Connection of cesspool or privy-well not to be made with sewer.

Water-closet or house drainage not to empty into cesspool or privy-well.

Rule 51. In rural districts waste-pipes from buildings may be connected with cesspools constructed for that special purpose, properly flagged or arched over, and not water-tight, by special permission of the Board of Health.

Waste-pipes may be connected with cesspools in rural districts.

Rule 52. Privy-vaults must be constructed as follows: Each building situate on an unsewered street must have a privy-vault not less than four (4) feet in diameter and ten (10) feet deep in the clear, lined with hard brick nine (9) inches in thickness, laid in cement mortar, and proved to be water-tight.

Construction of privy-vaults.

Rule 53. Privy-vaults shall not be located within two (2) feet of party lines, or within twenty (20) feet of a building when practicable; and before any privy-vault shall be constructed, application shall be made and a permit for same issued by the Board of Health.

Privy-vaults not to be located within 2 feet of party lines or 20 feet of a building.

Permit for construction of privy-vault required.

Rule 54. No opening will be permitted in the drain-pipe of any building for the purpose of draining a cellar, unless by special permission by the Board of Health.

No opening to be in drain-pipe for draining cellar unless by permission.

Rule 55. Cellar-drains shall be constructed as follows: By a system of French drains, or field tile, to a catch-basin, flagged over; the outlet pipe shall be properly trapped and connected with the house-drain, and shall also be provided with a back-pressure valve or stopcock the required size.

Construction of cellar drains.

FLOW OF WATER IN HOUSE-SERVICE PIPES.

(Thomson Meter Co.)

Condition of Discharge.	Pressure in Main, Lbs. per Sq. In.	Discharge in Cubic Feet per Minute from the Pipe. Nominal Diameters of Iron or Lead Service-pipe in Inches.								
		½	⅝	¾	1	1½	2	3	4	6
Through 35 feet of service-pipe, no back pressure.	30	1.10	1.92	3.01	6.13	16.58	33.34	88.16	173.85	444.63
	40	1.27	2.22	3.48	7.08	19.14	38.50	101.80	200.75	513.42
	50	1.42	2.48	3.89	7.92	21.40	43.04	113.82	224.44	574.02
	60	1.56	2.71	4.26	8.67	23.44	47.15	124.68	245.87	628.81
	75	1.74	3.03	4.77	9.70	26.21	52.71	139.39	274.89	703.03
	100	2.01	3.50	5.50	11.20	30.27	60.87	160.96	317.41	811.79
	130	2.29	3.99	6.28	12.77	34.51	69.40	183.52	361.91	925.58
Through 100 feet of service-pipe, no back pressure.	30	0.66	1.16	1.84	3.78	10.40	21.30	58.19	118.13	317.23
	40	0.77	1.34	2.12	4.36	12.01	24.59	67.19	136.41	366.30
	50	0.86	1.50	2.37	4.88	13.43	27.50	75.13	152.51	409.54
	60	0.94	1.65	2.60	5.34	14.71	30.12	82.30	167.06	448.63
	75	1.05	1.84	2.91	5.97	16.45	33.68	92.01	186.78	501.58
	100	1.22	2.13	3.36	6.90	18.99	38.89	106.24	215.68	579.18
	130	1.39	2.42	3.83	7.86	21.66	44.34	121.14	245.91	660.36
Through 100 feet of service-pipe and 15 feet vertical rise.	30	0.55	0.96	1.52	3.11	8.57	17.55	47.90	97.17	260.56
	40	0.66	1.15	1.81	3.72	10.24	20.95	57.20	116.01	311.09
	50	0.75	1.31	2.06	4.24	11.67	23.87	65.18	132.20	354.49
	60	0.83	1.45	2.29	4.70	12.94	26.48	72.28	146.61	393.13
	75	0.94	1.64	2.59	5.32	14.64	29.96	81.79	165.90	444.85
	100	1.10	1.92	3.02	6.21	17.10	35.00	95.55	193.82	519.72
	130	1.26	2.20	3.48	7.14	19.66	40.23	109.82	222.75	597.31
Through 100 feet of service-pipe and 30 feet vertical rise.	30	0.44	0.77	1.22	2.50	6.80	14.11	38.63	78.54	211.54
	40	0.55	0.97	1.53	3.15	8.68	17.79	48.68	98.98	266.59
	50	0.65	1.14	1.79	3.69	10.16	20.82	56.98	115.87	312.08
	60	0.73	1.28	2.02	4.15	11.45	23.47	64.22	130.59	351.73
	75	0.84	1.47	2.32	4.77	13.15	26.95	73.76	149.99	403.98
	100	1.00	1.74	2.75	5.65	15.58	31.93	87.38	177.67	478.55
	130	1.15	2.02	3.19	6.55	18.07	37.02	101.33	206.04	554.96

SAFE PRESSURES AND EQUIVALENT HEADS OF WATER FOR CAST-IRON PIPE OF DIFFERENT SIZES AND THICKNESSES.

(Calculated by F. H. Lewis from Fanning's Formula.)

Thickness.	Size of Pipe.																	
	4 Inches.		6 Inches.		8 Inches.		10 Inches.		12 Inches.		14 Inches.		16 Inches.		18 Inches.		20 Inches.	
	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.
$\frac{7}{16}$	112	258	49	112	18	42	....	....	....	....	....	....	....	....	....	....	....	....
$\frac{1}{2}$	224	516	124	280	74	171	44	101	24	55	....	....	....	....	....	....	....	....
$\frac{9}{16}$	336	774	199	458	130	300	89	205	62	143	42	97	....	....	....	....	....	....
$\frac{5}{8}$	....	....	274	631	186	429	132	304	99	228	74	170	56	129	41	95	....	....
$\frac{11}{16}$	....	....	....	....	....	....	177	408	137	316	106	244	84	194	66	152	51	118
$\frac{3}{4}$	....	....	....	....	....	....	224	516	174	401	138	316	112	258	91	210	74	170
$\frac{13}{16}$	....	....	....	....	....	....	....	....	212	488	170	392	140	323	116	267	96	221
$\frac{7}{8}$	....	....	....	....	....	....	....	....	249	574	202	465	168	387	141	325	119	274
$\frac{15}{16}$	....	....	....	....	....	....	....	....	....	....	234	538	196	452	166	382	141	325
1	....	....	....	....	....	....	....	....	....	....	266	612	224	516	191	440	164	378
$1\frac{1}{8}$	....	....	....	....	....	....	....	....	....	....	....	....	....	....	216	497	209	481
$1\frac{1}{4}$	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	....	256	589

SAFE PRESSURES AND EQUIVALENT HEADS OF WATER FOR CAST-IRON PIPE OF DIFFERENT SIZES AND THICKNESSES—(*Continued*).

Thickness.	Size of Pipe.																	
	22 Inches.		24 Inches.		27 Inches.		30 Inches.		33 Inches.		36 Inches.		42 Inches.		48 Inches.		60 Inches.	
	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet.	Pressure in Pounds.	Head in Feet
$\frac{11}{16}$	40	92	30	69	19	64												
$\frac{3}{4}$	60	138	49	113	36	83	24	55										
$\frac{13}{16}$	80	184	68	157	52	120	39	90										
$\frac{7}{8}$	101	233	86	198	69	159	54	124	42	97	32	74						
$\frac{15}{16}$	121	279	105	242	85	196	69	159	55	127	44	101						
1	142	327	124	286	102	235	84	194	69	159	57	131	38	88	24	55		
$1\frac{1}{8}$	182	419	161	371	135	311	114	263	96	221	82	189	59	136	43	99		
$1\frac{1}{4}$	224	516	199	458	169	389	144	332	124	286	107	247	81	187	62	143	34	78
$1\frac{3}{8}$			237	546	202	465	174	401	151	348	132	304	103	237	81	187	49	113
$1\frac{1}{2}$					236	544	204	470	178	410	157	362	124	286	99	228	64	147
$1\frac{5}{8}$							234	538	205	472	182	419	145	334	118	272	79	182
$1\frac{3}{4}$									233	537	207	477	167	385	136	313	94	217
$1\frac{7}{8}$													188	433	155	357	109	251
2													210	484	174	401	124	286
$2\frac{1}{8}$															193	445	139	320
$2\frac{1}{4}$															212	488	154	355
$2\frac{1}{2}$																	184	424
$2\frac{3}{4}$																	214	482

FORMULA FOR THICKNESS OF CAST-IRON WATER-PIPE.

$t = .00008hd + .01d + .36$ .... Shedd;
$t = .00006hd + .0133d + .296$ .... Warren Foundry;
$t = .000058hd + .0152 + .312$ .... Francis;
$t = .000048hd + .013d + .32$ .... Dupuit;
$t = .00004hd + .1\sqrt{d} + .15$ .... Box;
$t = .000135hd + .4 - .0011d$ .... Whitman;
$t = .00006(h + 230d) + .333 - .0033d$. .... Fanning;
$t = .00015hd + .25 - .0052d$ .... Meggs;

in which t = thickness in inches, h = head in feet, d = diameter.

SIZE AND WEIGHT OF LEAD PIPE.

Calibre.	Ultimate Strength.	Working Strength.	Weight per Foot. Lbs.	Oz.
1/8 inch tubing	....	....		3½
1/4 " extra-light tubing	....	....		4
1/4 " light tubing	....	....		6
1/4 " medium tubing	....	....		8
1/4 " strong tubing	....	....		10
1/4 " extra strong	....	....	1	2
3/8 " aqueduct	1187	296	0	8
3/8 " light	1342	335	0	12
3/8 " medium	1381	347	1	0
3/8 " strong	1627	406	1	8
3/8 " extra strong	1968	492	2	0
1/2 " aqueduct	782	195	0	10
1/2 " extra light	980	245	0	12
1/2 " light	1285	321	1	0
1/2 " medium	1393	343	1	4
1/2 " strong	1655	413	1	12
1/2 " extra strong	1787	446	2	8
5/8 " aqueduct	708	177	0	12
5/8 " extra light	795	198	1	4
5/8 " light	987	246	1	12
5/8 " medium	1152	288	2	0
5/8 " strong	1380	345	2	8
5/8 " extra strong	1548	387	3	0
3/4 " aqueduct	505	126	1	0
3/4 " extra light	782	195	1	8
3/4 " light	865	216	2	0
3/4 " medium	1072	268	2	4
3/4 " strong	1225	306	3	0
3/4 " extra strong	1462	365	3	8
1 " aqueduct	518	129	1	8
1 " extra light	562	140	2	0
1 " light	745	186	2	8
1 " medium	857	214	3	4
1 " strong	910	227	4	0
1 " extra strong	1230	307	4	12
1¼ " aqueduct	350	87	2	0
1¼ " extra light	420	105	2	8
1¼ " light	546	136	3	0
1¼ " medium	685	171	3	12
1¼ " strong	823	205	4	12
1¼ " extra strong	962	240	6	0
1½ " aqueduct	315	78	3	0

SIZE AND WEIGHT OF LEAD PIPE—(*Continued*).

Calibre.	Ultimate Strength.	Working Strength.	Weight per Foot. Lbs.	Oz.
1½ inch extra light	430	107	3	8
1½ " light	506	126	4	0
1½ " medium	628	157	5	0
1½ " strong	700	175	6	0
1½ " extra strong	742	185	7	8
1¾ " extra light	....	....	3	12
1¾ " light	....	....	4	8
1¾ " medium	318	79	5	8
1¾ " strong	....	93	6	8
1¾ " extra strong	....	116	8	0
2 " waste	200	50	3	0
2 " extra light	260	65	4	0
2 " light	360	90	5	0
2 " medium	405	101	7	0
2 " strong	511	127	8	0
2 " extra strong	611	152	9	0
2½ " 3/16 thick	....	....	8	0
2½ " ¼ "	....	....	11	0
2½ " 5/16 thick	....	....	14	0
2½ " ⅜ "	....	....	17	0
3 " waste	....	....	5	0
3 " 3/16 thick	....	....	9	0
3 " ¼ "	....	....	12	0
3 " 5/16 "	....	....	16	0
3 " ⅜ "	....	....	20	0
3½ " ¼ "	....	....	15	0
3½ " 5/16 "	....	....	18	0
3½ " ⅜ "	....	....	21	0
4 " waste	....	....	5	0
4 " ⅛ thick	....	....	7	0
4 " ¼ "	....	....	16	0
4 " 5/16 "	....	....	21	0
4 " ⅜ "	....	....	25	0
4 " 7/16 "	....	....	30	0
4½ " waste	....	....	6	0
5 " "	....	....	8	0

PURE BLOCK-TIN PIPE.

Calibre.	Wei'ht per Foot. Oz.	Calibre.	Weight per Foot. Lbs.	Oz.
⅛ inch strong	2½	½ inch double extra strong		15
¼ " extra strong	5	⅝ " extra strong		9
¼ " double extra strong	6	⅝ " double extra strong		14
5/16 " double extra strong	6½	¾ " extra strong		11
⅜ " extra strong	6	¾ " double extra strong	1	0
⅜ " double extra strong	8	1 " extra strong		14
½ " strong	6½	1 " double extra strong	1	4
½ " extra strong	10			

WEIGHTS AND SIZES OF SHEET LEAD.

Pounds per square foot	2½	3	3½	4	4½	5	6
Wire-gauge number...	19	18	17	16	15	14	13

Pounds per square foot	7	8	9	10	11	12
Wire-gauge number...	12	11	10	9	8	7

(A square foot of sheet lead $\frac{1}{16}$ of an inch thick weighs 4 pounds.)

APPROXIMATE WEIGHTS OF CAST-IRON SOIL-PIPE AND FITTINGS.

Standard.

Size, inches..........	2	3	4	5	6	8	10	12
Pipe..........pounds per foot	3½	4½	6½	8½	10	17	23	33
Crosses ....pounds each	5	10	12	16	24	.....	45	....
Double Y branch " "	8	11	18	26	37	.....	.....	....
Double hubs..... " "	3	4	6	8	10	16	26	....
Eighth bends.... " "	3	4¾	6	8	11	24	32¾	....
Half Y branches . " "	4½	6½	10	14	16	.....	.....	....
Quarter bends... " "	4	5½	8	10	14½	34	41	....
Reducers........ " "	....	3	4	6	8	9	.....	....
Sixth bends..... " "	3	4¾	6	8	11	24	32¾	....
Sleeves......... " "	2½	4	5	6	7	.....	.....	....
T branches...... " "	4	8	10	15	20	38	55	....
Traps........... " "	5½	10	19	26	35	.....	.....	....
Y branches...... " "	5	9	13	18	25	42	70	....
Size, inches................	....	....	....	2×8	3×8	4×12	5×12	6×8
Offsets, pounds each..........	....	....	....	5	8	15	20	22

Extra Heavy.

Size, inches..........	2	3	4	5	6	8	10	12
Pipe.........pounds per foot.	5½	9½	13	17	20	34	45	54
Crosses ....pounds each	10	20	24	32	48	85	.....	....
Double Y branch. " "	12	20	32	42	60	.....	.....	....
Double hubs..... " "	4½	7	8	11	14	28	47	....
Eighth bends.... " "	4¼	6¼	9½	12	16	35½	59½	....
Half Y branches . " "	9	13	18	24	30	.....	.....	....
Quarter bends... " "	6	8	12	15	20	44	74	....
Reducers........ " "	....	4	6	8	11	16	.....	....
Sixth bends..... " "	4¾	6¼	9½	12	16	35½	59½	....
Sleeves......... " "	4	6	7	9	10	.....	.....	....
T branches...... " "	7	13	20	25	34	50	104	....
Traps........... " "	9	18	28	45	68	.....	.....	....
Y branches...... " "	10	15	25	32	45	85	151	....
Size, inches................	....	....	....	2×8	3×8	4×12	5×12	6×8
Offsets, pounds each.........	....	....	....	9	15	23	30	38

CAPACITY AND SIZE OF GALVANIZED BOILERS.

Capacity.	Size.	Weight of Boiler.	Total Weight Filled with Water.
18 gallons........	3 feet by 12 inches	47	196
21 "	3½ " " 12 "	49	224
24 "	4 " " 12 "	57	257
24 "	3 " " 14 "	52	255
27 "	4½ " " 12 "	66	291
28 "	3½ " " 14 "	66	299
30 "	5 " " 12 "	72	322
32 "	4 " " 14 "	72	339
35 "	5 " " 13 "	76	367
36 "	6 " " 12 "	85	384
36 "	4½ " " 14 "	78	377
40 "	5 " " 14 "	85	418
42 "	4 " " 16 "	95	444
47 "	4½ " " 16 "	102	493
48 "	6 " " 14 "	102	503
52 "	5 " " 16 "	119	551
53 "	4 " " 18 "	119	562
63 "	6 " " 16 "	146	670
66 "	5 " " 18 "	150	699
79 "	6 " " 18 "	171	829
82 "	5 " " 20 "	192	875
98 "	6 " " 20 "	210	1026
100 "	5 " " 22 "	220	1053
120 "	6 " " 22 "	265	1264
120 "	5 " " 24 "	260	1259
144 "	6 " " 24 "	332	1531
168 "	7 " " 24 "	348	1747
192 "	8 " " 24 "	391	1990

TABLE OF WEIGHTS PER LINEAL FOOT OF SEAMLESS BRASS AND COPPER TUBING.

Iron Pipe Sizes.

Made to correspond with iron tubes and to fit iron tube fittings.

Same as Iron Size.	Exact Outside Diameter.	Exact Inside Diameter.	About Inside Diameter.	Weight per Foot.	
	Decimals.	Decimals.	Fractions.	Brass.	Copper.
Inches.	Inches.	Inches.	Inches.	Lbs.	Lbs.
⅛	.405	.281	¼	.25	.26
¼	.540	.375	11/32	.43	.45
⅜	.675	.484	15/32	.62	.65
½	.840	.625	⅝	.90	.95
¾	1.04	.822	27/32	1.25	1.31
1	1.315	1.062	1 3/32	1.70	1.79
1¼	1.66	1.368	1 11/32	2.50	2.63
1½	1.90	1.600	1 19/32	3.00	3.15
2	2.375	2.062	2 1/16	4.00	4.20
2½	2.875	2.500	2 7/16	5.75	6.04
3	3.50	3.062	3 1/16	8.30	8.72
3½	4.00	3.5000	3½	10.90	11.45
4	4.50	4.000	4 1/32	12.70	13.33
4½	5.00	4.5000	4 17/32	13.90	14.60
5	5.563	5.062	5 1/32	15.75	16.54
6	6.625	6.125	6 1/16	18.31	19.23

SEAMLESS BRASS AND COPPER TUBING—(*Continued*).

Extra-heavy Iron Pipe Sizes.

Same as Extra-heavy Iron Pipe.	Exact Outside Diameter.	Exact Inside Diameter.	Approximate Weight in Pounds per Foot.	
			Brass.	Copper.
Inches.	Inches.	Inches.	Lbs.	Lbs.
1/8	.405	.205	.370	.389
1/4	.504	.294	.625	.651
3/8	.675	.421	.830	.872
1/2	.840	.542	1.200	1.260
3/4	1.050	.736	1.660	1.743
1	1.315	.951	2.360	2.478
1 1/4	1.660	1.272	3.300	3.465
1 1/2	1.900	1.494	4.250	4.462
2	2.375	1.933	5.460	5.733
2 1/2	2.875	2.315	8.300	8.715
3	3.500	2.892	11.200	11.760
3 1/2	4.00	3.358	13.700	14.385
4	4.50	3.818	16.500	17.325
5	5.563	4.813	22.800	23.940
6	6.625	5.750	32.000	33.600

SIZE, WEIGHTS, ETC., OF VITRIFIED SALT-GLAZED SEWER-PIPE.

Calibre of Pipe.	Thickness of Pipe.	Weight per Foot.	Feet to 15-ton Car Load.
3 inches	1/2 inch	6 pounds	5000
4 "	1/2 "	7 1/2 "	4000
5 "	5/8 "	11 1/2 "	2610
6 "	3/4 "	16 "	1880
8 "	3/4 "	22 "	1366
10 "	7/8 "	31 "	970
12 "	7/8 "	41 "	734
14 "	1 "	50 "	600
16 "	1 1/8 inches	66 "	456
18 "	1 1/4 "	80 "	376
20 "	1 1/4 "	90 "	334
22 "	1 3/8 "	100 "	300
24 "	1 1/2 "	120 "	250
30 "	1 3/4 "	190 "	158

DOUBLE-STRENGTH PIPE.

Calibre of Pipe.	Thickness of Pipe.	Weight per Foot.	Feet to 15-ton Car Load.
15 inches	1 1/4 inches	65 pounds	462
18 "	1 1/2 "	100 "	300
21 "	1 3/4 "	132 "	228
24 "	2 "	175 "	172
30 "	2 1/2 "	260 "	116

TERRA-COTTA FLUE-LININGS.

Inside Measure.	Outside Measure.	Form.	Weight per Foot.	Feet to Car Load of 15 Tons.
5 inches	7 inches	Round	14 pounds	2144
6 "	8 "	"	19 "	1580
8 "	10 "	"	22 "	1364
10 "	12½ "	"	30 "	1000
3½ × 7½ "	4½ × 8½ "	Square	10 "	3000
7 × 7 "	8½ × 8½ "	"	20 "	1500
7 × 11½ "	8½ × 13 "	"	30 "	1000
7 × 15½ "	8½ × 17 "	"	33 "	910
11½ × 11½ "	13 × 13 "	"	37 "	810
11½ × 15½ "	13 × 17 "	"	40 "	750
15½ × 15½ "	17 × 17 "	"	50 "	600

Gas-piping, etc.—The gas-pipes in a building should be wrought iron or soft steel of standard make. The fittings should be galvanized, as the zinc coating makes the fittings more solid and durable. Each piece of pipe before being put in place should be looked or blown through to see if it is clear of any stoppage. No gas-fitters' cement should be permitted to be used in any joints except the caps on the outlets. In running a line of pipe it should run in as direct a line and with as few turns as possible. All pipes should be run with a uniform fall to the riser or starting-point, so that any water which may gather will run back to the main. In taking off branches or outlets from any run of pipe they should always be taken out at the side and all drop lights should be taken from a tee fitting in a short branch and the branch extended about a foot beyond the tee and capped; this insures the drop to hang plumb.

Bracket lights should always be brought from the floor below, as gas should never be made to run down a pipe where it is possible to do otherwise, where convenient separate risers should be run to each floor and controlled by stopcocks in the cellar where they can be got at. When pipes cross wooden beams or joists, the pipes should be run across the top of the beams and the beams notched as little as possible, and not more than two feet from a bearing.

When the pipes are all in place the superintendent should go over them and see that all outlets are provided for, and that all pipe are laid in the best possible manner. He should then have them tested to 8 or 10 pounds pressure, which should be left on for about twenty-five minutes. After the test is

made, a good scheme is to leave the pressure on and loosen the cap on each outlet separately and notice if the pressure goes down as each one is loosened; this will show if the pipes are all clear, or if any of them contains any obstruction. The test on the pipes should be repeated just before the plastering is commenced, and again when it is finished.

The following table shows the size of pipes and number of burners which they will supply:

Greatest Number of Feet to be Run.	Size of Pipe.	Greatest Number of Burners to be Supplied.	Greatest Number of Feet to be Run.	Size of Pipe.	Greatest Number of Burners to be Supplied.
20 feet	⅜ inch	2	150 feet	1½ inches	70
30 "	½ "	4	200 "	2 "	140
50 "	¾ "	15	300 "	2½ "	225
70 "	1 "	25	400 "	3 "	300
100 "	1¼ inches	40	500 "	4 "	500

Computing the Pressure.—Pressures which have been measured in inches of water or mercury may be translated in pounds per square inch or foot by multiplying the reading by the following figures:

One inch of water at 62° equals 5.2 pounds per square foot.

One inch of water at 62° equals 0.0361 pound per square inch.

One inch of mercury at 62° equals 0.4897 pound per square inch.

Pressures per square inch or square foot may be converted into inches or feet of water, or inches of mercury, by multiplying the pressure by the following figures:

One pound per square foot equals 0.1923 inch of water.

One pound per square inch equals 27.7 inches of water at 62°.

One pound per square inch equals 2.042 inches of mercury at 62°.

Increase of Pressure.—The increase of pressure in each 10 feet of rise in pipes with gas of various densities is as follows:

Rise in pressure (ins. of water).........	0	.0147	.0293	.044	.058	.073	.088	.102
Density of gas.......	1	.9	.8	.7	.6	.5	.4	.3

Example.—The pressure in the basement at the meter is 1.2 of water; what will be the pressure at the sixth story, 70 feet above, the density of the gas being .4?

Solution.—The table shows that the increase will be 0.088 inch for each 10 feet of rise, therefore 0.088×7 equals 0.616 inch increase. Then the pressure at the sixth story equals $1.2 + 0.616 = 1.816$.

CAPACITY OF GAS-PIPES UNDER A PRESSURE OF 10.4 LBS. PER SQUARE FOOT.

Diameter of Pipe in Inches.	Maximum Length in Feet.	Capacity per Hour.	
		Coal Gas, Cubic Feet.	Gasoline Gas, Cubic Feet.
1/4	6	10	....
3/8	20	15	10
1/2	30	30	20
3/4	50	100	75
1	70	175	125
1 1/4	100	300	200
1 1/2	150	500	350
2	200	1000	700
2 1/2	300	1500	1100
3	450	2250	1500
4	600	3750	2500

Flow of Gas in Pipes.—If d = diameter of pipe in inches; Q = quantity of gas delivered in cubic feet per hour; l = length of pipe in yards; h = pressure in inches of water-column; s = specific gravity of the gas, air being one; then

$$Q = 1000\sqrt{\frac{d^5 h}{sl}};\ \text{(Molesworth)};$$

$$Q = 1350 d^2 \sqrt{\frac{dh}{sl}}\ \text{(King's Treatise on Coal-gas)};$$

$$Q = 1290\sqrt{\frac{d^5 h}{d(s+l)}}\ \text{(J. P. Gill, \textit{Am. Gas-light Jour.}, 1894)}.$$

Mr. Gill's formula is said to be based on experimental data, and to make allowance for obstructions by tar, etc., that tend to check the flow of gas through the pipe.

An experiment made by Mr. Klegg, in London, on a 4-inch pipe 6 miles long gave a discharge that corresponds very closely with that computed by the use of Molesworth's formula.

MAXIMUM SUPPLY OF GAS THROUGH PIPES IN CUBIC FEET PER HOUR, SPECIFIC GRAVITY BEING 0.45.

Formula, $Q = 1000\sqrt{d^5h \div sl}$. (Molesworth.)

LENGTH OF PIPE = 10 YARDS.

Diameter of Pipe in Inches.	Pressure by the Water-gauge in Inches.									
	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9	1.0
3/8	13	18	22	26	29	31	34	36	38	41
1/2	26	37	46	53	59	64	70	74	79	83
3/4	73	103	126	145	162	187	192	205	218	230
1	149	211	258	298	333	365	394	422	447	471
1 1/4	260	368	451	521	582	638	689	737	781	823
1 1/2	411	581	711	821	918	1006	1082	1162	1232	1299
2	843	112	1460	1686	1886	2066	2231	2385	2530	2667

LENGTH OF PIPE = 100 YARDS.

Diameter of Pipe in Inches.	Pressure by the Water-gauge in Inches.										
	0.1	0.2	0.3	0.4	0.5	0.75	1.0	1.25	1.5	2.0	2.5
1/2	8	12	14	17	19	23	26	29	32	36	42
3/4	23	32	42	46	51	63	73	81	89	103	115
1	47	67	82	94	105	129	149	167	183	211	236
1 1/4	82	116	143	165	184	225	260	291	319	368	412
1 1/2	130	184	225	260	290	356	411	459	503	581	649
2	267	377	462	533	596	730	843	943	1033	1193	1333
2 1/2	466	659	807	932	1042	1276	1473	1647	1804	2083	2329
3	735	1039	1270	1470	1643	2012	2323	2598	2846	3286	3674
3 1/2	1080	1528	1871	2161	2416	2958	3416	3820	4184	4831	5402
4	1508	2133	2613	3017	3373	4131	4770	5333	5842	6746	7542

LENGTH OF PIPE = 1000 YARDS.

Diameter of Pipe in Inches.	Pressure by the Water-gauge in Inches.						
	0.5	0.75	1.0	1.5	2.0	2.5	3.0
1	33	41	47	58	67	75	82
1 1/2	92	113	130	159	184	205	226
2	189	231	267	327	377	422	462
2 1/2	329	403	466	571	659	737	807
3	520	636	735	900	1039	1162	1273
4	1067	1306	1508	1847	2133	2385	2613
5	1863	2282	2635	3227	3727	4167	4564
6	2939	3600	4157	5091	5879	6573	7200

MAXIMUM SUPPLY OF GAS THROUGH PIPES, ETC.—(*Continued*).

LENGTH OF PIPE = 5000 YARDS.

Diameter of Pipe in Inches.	Pressure by the Water-gauge in Inches.				
	1.0	1.5	2.0	2.5	3.0
2	119	146	169	189	207
3	329	402	465	520	569
4	675	826	955	1067	1168
5	1179	1443	1667	1863	2041
6	1859	2277	2629	2939	3220
7	2733	3347	3865	4321	4734
8	3816	4674	5397	6034	6610
9	5123	6274	7245	8100	8873
10	6667	8165	9428	10541	11547
12	10516	12880	14872	16628	18215

Where there is apt to be trouble from frost no pipe less than ¾ inch should be used, and in extremely cold climates the smallest size should not be less than 1 inch.

To provide for the resistance due to bends, one rule is to allow a pressure of 0.204 inch of water-column for each right-angled elbow.

AQUEOUS VAPOR CONTAINED IN 1000 CUBIC FEET OF GAS AT INDICATED TEMPERATURE.

Temp. Degrees.	Volume Aqueous Vapor.	Temp. Degrees.	Volume Aqueous Vapor.	Temp. Degrees.	Volume Aqueous Vapor.
40	9.33	54	15.33	68	24.06
41	9.73	55	15.86	69	24.83
42	10.13	56	16.40	70	25.66
43	10.53	57	16.93	71	26.53
44	10.93	58	17.53	72	27.40
45	11.33	59	18.10	73	28.30
46	11.73	60	18.66	74	29.23
47	12.13	61	19.23	75	30.20
48	12.53	62	19.80	76	31.20
49	12.93	63	20.50	77	32.20
50	13.33	64	21.20	78	33.23
51	13.80	65	21.90	79	34.23
52	14.26	66	22.60	80	35.33
53	14.80	67	23.30	81	36.43

NATIONAL TUBE COMPANY.

Black or Galvanized Standard Weight Pipe.

Diameter			Thickness.	Circumference.		Transverse Areas.			Nominal Weight per Foot. Pounds	Threads per Inch
Nominal.	External.	Internal.		External.	Internal.	External.	Internal.	Metal.		
1/8	.405	.269	.068	1.272	.845	.1288	.0568	.0720	.241	27
1/4	.540	.364	.088	1.696	1.144	.2290	.1041	.1249	.42	18
3/8	.675	.493	.091	2.121	1.549	.3578	.1909	.1669	.559	18
1/2	.840	.622	.109	2.639	1.954	.5542	.3039	.2503	.837	14
3/4	1.050	.824	.113	3.299	2.589	.8659	.5333	.3326	1.115	14
1	1.315	1.047	.134	4.131	3.289	1.3581	.8609	.4972	1.668	11½
1¼	1.660	1.380	.140	5.215	4.335	2.1642	1.4957	.6685	2.244	"
1½	1.900	1.610	.145	5.969	5.058	2.8353	2.0358	.7995	2.678	"
2	2.375	2.067	.154	7.461	6.494	4.4301	3.3556	1.074	3.609	"
2½	2.875	2.467	.204	9.032	7.750	6.4918	4.7800	1.712	5.739	8
3	3.500	3.066	.217	10.996	9.632	9.6211	7.3827	2.238	7.536	"
3½	4.000	3.548	.226	12.566	11.146	12.566	9.886	2.680	9.001	"
4	4.500	4.026	.237	14.137	12.648	15.904	12.730	3.174	10.665	"
4½	5.000	4.508	.246	15.708	14.162	19.635	15.960	3.675	12.34	"
5	5.563	5.045	.259	17.477	15.849	24.306	19.985	4.321	14.502	"
6	6.625	6.065	.280	20.813	19.054	34.472	28.886	5.586	18.762	"
7	7.625	7.023	.301	23.955	22.063	45.664	38.743	6.921	23.271	"
8	8.625	7.981	.322	27.096	25.073	58.426	50.021	8.405	28.177	"
9	9.625	8.937	.344	30.238	28.076	72.760	62.722	10.04	33.701	"
10	10.750	10.018	.366	33.772	31.472	90.763	78.822	11.94	40.065	"
11	11.750	11.000	.375	36.913	34.558	108.43	95.034	13.40	45.95	"
12	12.750	12.000	.375	40.055	37.699	127.68	113.09	14.59	48.985	"

Allow variation in weight per foot of 5 per cent above and 5 per cent below. Cannot cut closer to length than 1/16 inch. Shipped threads and couplings unless otherwise ordered.

NATIONAL TUBE COMPANY.

STANDARD EXTRA STRONG PIPE.

Diameter.			Thickness.	Circumference.		Transverse Areas.			Nominal Weight per Foot. Pounds	Threads per Inch.
Nominal.	External.	Internal.		External.	Internal.	External.	Internal.	Metal.		
1/8	.405	.205	.100	1.272	.644	.129	.033	.096	.29	27
1/4	.540	.294	.123	1.696	.924	.229	.068	.161	.54	18
3/8	.675	.421	.127	2.121	1.323	.358	.139	.219	.74	"
1/2	.840	.542	.149	2.639	1.703	.554	.231	.323	1.09	14
3/4	1.050	.736	.157	3.299	2.312	.866	.425	.441	1.39	"
1	1.315	.951	.182	4.131	2.988	1.358	.710	.648	2.17	11½
1¼	1.660	1.272	.194	5.215	3.996	2.164	1.271	.893	3.00	"
1½	1.900	1.494	.203	5.969	4.694	2.835	1.753	1.082	3.63	"
2	2.375	1.933	.221	7.461	6.073	4.430	2.935	1.495	5.02	"
2½	2.875	2.315	.280	9.032	7.273	6.492	4.209	2.283	7.67	8
3	3.500	2.892	.304	10.996	9.086	9.621	6.569	3.052	10.25	"
3½	4.000	3.358	.321	12.566	10.549	12.566	8.856	3.710	12.47	"
4	4.500	3.818	.341	14.137	11.995	15.904	11.449	4.455	14.97	"
4½	5.000	4.280	.360	15.708	13.446	19.635	14.387	5.248	18.22	"
5	5.563	4.813	.375	17.477	15.120	24.306	18.193	6.113	20.54	"
6	6.625	5.751	.437	20.813	18.067	34.472	25.976	8.496	28.58	"
7	7.625	6.625	.500	23.955	20.813	45.664	34.472	11.192	37.67	"
8	8.625	7.625	.500	27.096	23.955	58.426	45.664	12.762	43.00	"
9	9.625	8.625	.500	30.238	27.096	72.760	58.426	14.334	48.25	"
10	10.750	9.750	.500	33.772	30.631	90.763	74.662	16.101	54.25	"
12	12.750	11.750	.500	40.055	36.914	127.68	108.43	19.25	65.00	"

Allow variation in weight per foot of 5 per cent above and 5 per cent below standard. Cannot cut to length closer than 1/16 inch. Shipped plain ends unless otherwise ordered. Where extra-strong pipe is ordered with threads and couplings, our regular line-pipe couplings will be furnished unless otherwise specified.

NATIONAL TUBE COMPANY.

STANDARD DOUBLE EXTRA STRONG PIPE.

Diameter.			Thickness.	Circumference.		Transverse Areas.			Nominal Weight per Foot. Pounds.	Threads per Inch.
Nominal.	External.	Internal.		External.	Internal.	External.	Internal.	Metal.		
½	.840	.244	.298	2.639	.767	.554	.047	.507	1.7	14
¾	1.050	.422	.314	3.299	1.326	.866	.140	.726	2.44	14
1	1.315	.587	.364	4.131	1.844	1.358	.271	1.087	3.65	11½
1¼	1.660	.885	.388	5.215	2.780	2.164	.615	1.549	5.2	"
1½	1.900	1.088	.406	5.969	3.418	2.835	.930	1.905	6.4	"
2	2.375	1.491	.442	7.461	4.684	4.430	1.744	2.686	9.02	"
2½	2.875	1.755	.560	9.032	5.514	6.492	2.419	4.073	13.68	8
3	3.500	2.284	.608	10.996	7.176	9.621	4.097	5.524	18.56	"
3½	4.000	2.716	.642	12.566	8.533	12.566	5.794	6.772	22.75	"
4	4.500	3.136	.682	14.137	9.852	15.904	7.724	8.180	27.48	"
4½	5.000	3.564	.718	15.708	11.197	19.635	9.976	9.659	32.53	"
5	5.563	4.063	.750	17.477	12.764	24.306	12.965	11.341	38.12	"
6	6.625	4.875	.875	20.813	15.315	34.472	18.665	15.807	53.11	"
7	7.625	5.875	.875	23.955	18.457	45.664	27.109	18.555	62.38	"
8	8.625	6.875	.875	27.096	21.598	58.426	37.122	21.304	71.62	"

Allow variation of 5 per cent above and 5 per cent below standard in weight per foot. Cannot cut to length closer than $\frac{1}{16}$ inch. Shipped plain ends unless otherwise ordered.

How Steel and Wrought-iron Pipes are Made.[1]—LAP-WELDING.—The plate for the larger sizes of pipe is first laid upon a travelling-table and the edges scarfed or bevelled. It is then heated in a bending furnace and rolled up into pipe form with the scarfed edges overlapping. The plates for the smaller sizes are formed up by being drawn through the die shown in the accompanying illustration. This consists of a stout cast-iron bending die the front half of which next the furnace door is flared out to receive the plate. Inside the die is a mandrel of the shape shown in the smaller engraving, whose rear portion is of about the size of the finished pipe. As the plate is pushed out of the furnace it is drawn by a pair of tongs through the die the flaring sides of which curve the plate until its edges meet and lap as they pass through the tubular end of the die. The plates, now bent up into form and known as skelp, are heated in a gas-fired welding furnace, and when they have reached a welding heat the skelp is pushed through the door at the back of the furnace into the welding-rolls, which are located just outside the door. The rolls, which are concave, are curved to the desired radius, and between them, held in position by a long bar, is a "ball," or mandrel, of the same diameter as the inside of the pipe. As the skelp passes through the rolls, its lapping edges are squeezed together between the rolls and the mandrel and a perfect weld is made. Each piece of pipe is carefully examined and all doubtful welds are rejected. The rough pipe then goes through the sizing rolls, in which it is brought to the exact diameter. Then it passes to the cross-straightening rolls the axes of which are inclined at an angle, as shown in the accompanying illustration. By this time it is perfectly true and straight, and to prevent it from warping as it cools, it is rolled and conveyed on a cooling-table to a straightening-machine, where it receives its final straightening in dies controlled by hydraulic pressure. The ends are then cut off, and after being threaded and the coupling put on, the pipe is tested in a hydraulic testing-machine, the smaller sizes at from 600 to 1500 pounds, the larger at from 500 to 750 pounds to the square inch. For oil-well tubing the tests run as high as 2500 pounds to the square inch.

BUTT-WELDING.—The smaller sizes of pipes are butt-welded. The plates, which are not scarfed as in the larger pipe, are

[1] *Scientific American.*

heated in the furnace, and when raised to a welding heat are drawn through a bell-shaped die the diameter of which is a little less than that of the skelp. The pressure thus induced is sufficient to squeeze the edges together and form the plate into a perfectly welded pipe.

WEIGHTS OF CAST-IRON PIPE IN POUNDS.

Standard Water-pipe.

Lbs. Lead per Joint.	Ounces Jute per Joint.	Size Pipe.	Thickness.	Weight per Foot with Bell.	Weight per Length with Bell.	Weight of Bell.
3	2.8	3″	$\frac{15}{32}''$	17	204	12
5.5	3.5	4″	$\frac{15}{32}''$	22	264	12
8	5.0	6″	$\frac{1}{2}''$	34	408	24
11	7.0	8″	$\frac{17}{32}''$	47	564	36
14	8.5	10″	$\frac{9}{16}''$	64	768	48
18	11.0	12″	$\frac{5}{8}''$	82	984	60
21	13.0	14″	$\frac{11}{16}''$	105	1260	72
24	15.0	16″	$\frac{3}{4}''$	133	1596	108
27	16.0	18″	$\frac{13}{16}''$	160	1920	120
31	20.0	20″	$\frac{7}{8}''$	190	2280	144
36	24.0	24″	1″	260	3120	180
50	33.0	30″	$1\frac{1}{8}''$	360	4320	204
76	48.0	36″	$1\frac{1}{4}''$	488	5856	360
95	58.0	42″	$1\frac{3}{8}''$	625	7500	468
112	70.0	48″	$1\frac{9}{16}''$	830	9960	648
170	100.0	60″	$1\frac{7}{8}''$	1220	14640	960

Standard Gas-pipe.

Lbs. Lead per Joint.	Ounces Jute per Joint.	Size Pipe.	Thickness.	Weight per Foot with Bell.	Weight per Length with Bell.	Weight of Bell.
3	2.8	3″	$\frac{25}{64}''$	14	168	12
5.5	3.5	4″	$\frac{13}{32}''$	19	228	12
8	5.0	6″	$\frac{7}{16}''$	30.5	366	18
11	7.0	8″	$\frac{15}{32}''$	41	492	24
14	8.5	10″	$\frac{1}{2}''$	56	672	48
18	11.0	12″	$\frac{35}{64}''$	74	888	60
21	13.0	14″	$\frac{19}{32}''$	92	1104	72
24	15.0	16″	$\frac{41}{64}''$	112	1344	96
27	16.0	18″	$\frac{11}{16}''$	133	1596	108
31	20.0	20″	$\frac{47}{64}''$	159	1908	120
36	24.0	24″	$\frac{51}{64}''$	205	2460	132
50	33.0	30″	$\frac{55}{64}''$	275	3300	168
76	48.0	36″	$\frac{61}{64}''$	368	4416	304

The above tables show the weights which have been adopted by the United States Cast Iron Pipe and Foundry Company as standard weights for water- and gas-pipe respectively for ordinary service.

LIST OF STANDARD SPECIALS.

(Approximate weight.)

Size in In.	Wt. in Lbs.
Crosses.	
2	40
3	110
3×2	90
4	140
4×3	114
4×2	90
6	200
6×4	160
6×3	160
8	330
8×6	280
8×4	265
8×3	225
10	595
10×8	415
10×6	430
10×4	390
10×3	370
12	740
12×10	650
12×8	620
12×6	540
12×4	525
12×3	495
14×10	750
14×8	625
14×6	570
16	1100
16×14	1070
16×12	1000
16×10	1010
16×8	825
16×6	700
16×4	690
18	1560
20	1790
20×12	1370
20×10	1225
20×8	1335
20×6	1000
20×4	1000
24	2400
24×20	2020
24×6	1340
30×20	2635
30×12	2250
30×8	1995
Tees.	
2	28
3	85
3×2	76
4	110
4×3	120
4×2	87
6	170
6×4	145
6×3	145
6×2	75
8	290
8×6	280
8×4	220
8×3	220
10	390
10×8	345
10×6	370
10×4	350
10×3	330
12	600
12×10	555
12×8	530
12×6	525
12×4	550
14×12	650
14×10	650
14×8	575
14×6	545
14×4	525
14×3	490
16	790
16×14	850
16×12	850
16×10	825
16×8	755
16×6	680
16×4	655
18	1235
20	1475
20×16	1115
20×12	1025
20×10	1090
20×8	1070
20×6	875
20×4	845
24×10	1465
24	2000
24×20	1730
24×12	1425
24×8	1375
24×6	1450
30	3025
30×24	2640
30×20	2380
30×12	2035
30×10	2050
30×6	1825
36	5140
36×30	4200
36×12	4050
45° Branch Pipes.	
3	90
4	125
6	205
6×6×4	145
8	330
8×6	330
24	2765
24×24×20	2145
30	4170
36	10300
Sleeves.	
2	10
3	30
4	45
6	100
8	120
10	140
12	190
14	208
16	350
18	340
20	400
24	710
30	965
36	1200

LIST OF STANDARD SPECIALS.—(*Continued*).

Size in In.	Wt. in Lbs.
90° Elbows.	
2	14
3	34
4	55
6	120
8	150
10	260
12	370
14	450
16	660
18	850
20	900
24	1400
30	3000
$\frac{1}{8}$ or 45° Bends.	
3	30
4	70
6	95
8	150
10	200
12	290
16	510
18	580
20	780
24	1425
30	2000
$\frac{1}{16}$ or $22\frac{1}{2}$° Bends.	
4	65
6	150
8	155
10	205
12	260
16	450
24	1280
30	2000

Size in In.	Wt. in Lbs.
Reducers.	
3×2	35
4×3	45
4×2	40
6×4	95
6×3	70
8×6	126
8×4	116
8×3	116
10×8	200
10×6	180
10×4	160
12×10	320
12×8	300
12×6	250
12×4	250
14×12	475
14×10	400
14×8	390
14×6	285
16×12	475
16×10	435
20×16	690
20×14	575
20×12	540
20×8	400
24×20	860
30×24	1305
30×18	1385
36×30	1730
Angle Reducers for Gas.	
6×4	95
6×3	70
S Pipes.	
4	105
6	190

Size in In.	Wt. in Lbs.
Plugs.	
2	3
3	10
4	10
6	15
8	30
10	46
12	66
14	90
16	100
18	130
20	150
24	185
30	370
Caps.	
3	20
4	25
6	60
8	75
10	100
12	120
16	265
Drip-boxes.	
4	295
6	330
8	375
10	875
20	1420

TIN AND SHEET-METAL WORK. PAINTING IRONWORK, ETC. ELECTRIC WIRING, ETC. HEATING.

Tin and Sheet-metal Work.—Tin for flat roofs is usually put on with the ordinary flat lock joint, the sheets of tin being nailed under the lock. After the sheets are nailed and

hooked together the hook joints are beaten down with a wooden mallet and then soldered.

When it is desired to make some allowance for contraction and expansion the sheets should be fastened with tin clips nailed to the roof as shown by Fig. 228; in this way there are no nails through the sheets of tin, but they are held in place by the clips. Fig. 229 shows a section of the joint.

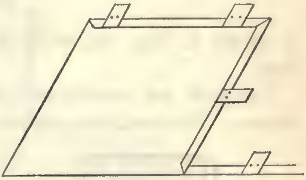


Fig. 228.

Standing seam roofs are also fastened with clips nailed to the sheathing and turned down in the standing seam. Fig. 230, 1, 2, 3, shows a standing seam roof in the different stages of construction.

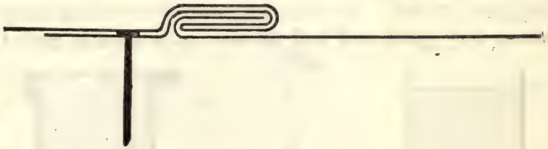


Fig. 229.

Fig. 230, at 5, shows the joint turned down in a flat lock joint.

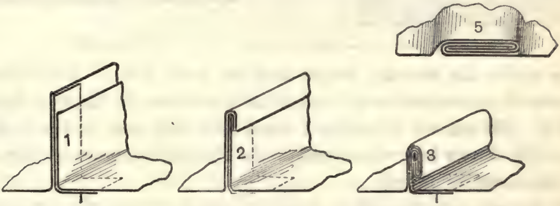


Fig. 230.

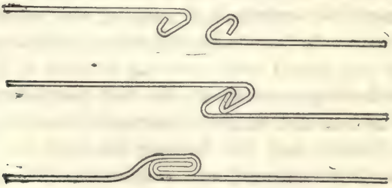


Fig. 231.

In standing seam roofs or any roof where the tin is laid in long lengths the cross-joints should be double-locked; this is shown in Fig. 231, while Fig. 232 shows the ordinary single lock.

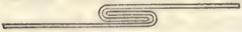


FIG. 232.

Tin roofs are sometimes put on in lengths running with the slope of the roof, the strips of tin being turned up and laid between strips of wood, as shown by Fig. 233. This method is used to make an allowance for expansion and contraction.

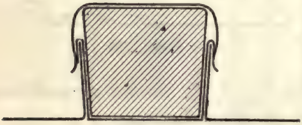


FIG. 233.

Figs. 234 and 235 show another method of putting a cap over the wooden strip; this makes a very good roof and all the tin is held in place by the clips under the wooden strips and the lock joint. The different stages of construction of the joint are shown in the two figures.

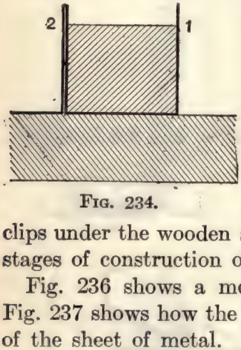


FIG. 234.

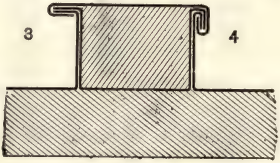


FIG. 235.

Fig. 236 shows a method used for zinc and copper, while Fig. 237 shows how the cross-joints should be made at the ends of the sheet of metal.

A rise or step should be made in the roof and the two sheets of metal turned and locked as shown in Fig. 237. In working zinc care must be exercised in making the bends and angles, for if they are made too sharp the metal is liable to crack.

Wherever any metal roof covering finishes at a wall or any place where flashing is necessary the roof metal should be turned up 8 or 10 inches and securely fastened; then this metal should be counter-flashed and the flashing let into the joint of the wall at least 2 inches and well cemented. This is one part of the work that the superintendent should pay particular attention to, so as to get everything water-tight.

In all metal roofing the main points are to get the roof water-tight and to make provision for expansion and contraction.

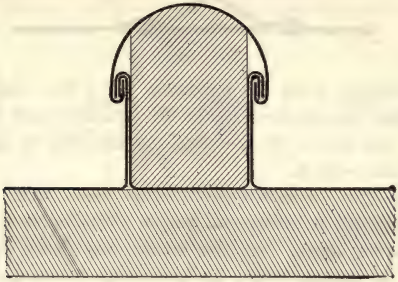


FIG. 236.

PAINTING.—As soon as the roofing is in place and the joints all soldered, it should then be painted. Before painting the superintendent should see that all surplus resin and grease are cleaned off so the paint can take hold of the metal.

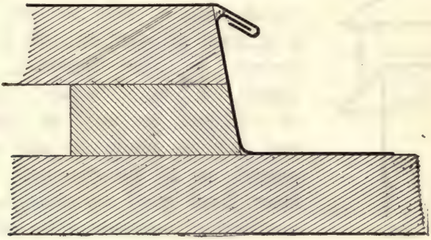


FIG. 237.

VENT AND HOT-AIR PIPES.—The superintendent must be particular to see that these pipes are located right and the openings put at the proper height. When the opening is at the bottom it should be just above the wood base, so the flange of the register plate will set on top of the wood base. In vent-pipes the top opening should be as near the ceiling or cornice as possible.

The hot-air openings are placed at various heights according to the system of heating employed, and these heights should be indicated on the drawings.

All pipes should run as direct and have as few turns as possible.

Any pipe having a width of 18 inches or over should be stiff-

ened by having ribs riveted across them about 2 feet apart. Fig. 238 shows a section of the rib.

FIG. 238.

In metal-work, such as cornices, etc., the superintendent must see that the desired forms or brackets are fastened securely and the metal is fastened as desired to the brackets and made water-tight.

GUTTERS.—The superintendent must see that all gutters have sufficient fall to insure all water to be carried to the conductor, or down spout. At the intake the down spout should be enlarged to about twice its area and covered with a wire screen to prevent leaves or dirt from entering the pipe.

VENTILATORS.—There are a number of various kinds and styles of ventilators on the market, the majority of which are sold under patent. Nearly all of the various ventilators give good satisfaction, but there is one, known as The Emerson Ventilator, shown by Fig. 239, and which is just as efficient as any on the market, and can be made by any one, as the patent on it has expired. This ventilator gives good satisfaction either for ventilation purposes or for smoke, as its shape insures an upward draft no matter which way the wind is blowing.

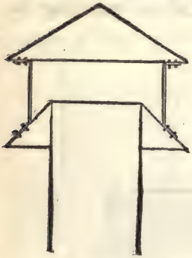


FIG. 239.

TIN-PLATE.—Tin-plate is sheet iron, or steel coated with tin. Terne-plate is a plate of sheet iron coated with tin and lead and is inferior in quality to the tin-plate. The best plates are those known to be made by the "charcoal" or "old" process.

Plates coated with tin are known as "bright tin," while those coated with a mixture of tin and lead are known as "terne" or "dull" plates.

Plates are made in two thicknesses, IC and IX. The IC is No. 30 gauge and weighs .5 pounds to the square foot; the IX is No. 28 gauge and weighs .625 pounds per foot.

Imperfect sheets are called "wasters," and the letter W on a box after the IC or IX indicates that the box contains imperfect sheets.

COMPOSITION AND FUSING-POINTS OF SOLDER.

Kind.	Hard.			Soft.			Fusing-point.
	Zinc.	Copper.	Silver.	Tin.	Lead.	Bismuth.	
Spelter, hardest	1						700°
" hard	2	3					550°
" soft	1	1					
" fine	2	2	$\frac{1}{4}$				
Silver, hard		1	4				
" medium		1	3				
" soft		1	2				
Plumbers', coarse				1	3		480°
" ordinary				1	2		441°
" fine				2	3		400°
Tinners'				1	1		370°
For tin pipe				3	2		330°
" " "				4	4	1	

Solder may be tested by melting, when, if a great many bright spots appear floating on the top, it must be considered too soft or fine, while if the spots are totally absent, it contains too much lead. Tin spots about three-eighths of an inch in diameter indicate good solder.

Fluxes are used to aid in the fusion of solder and to clean the surface of the metals to be soldered. Those commonly used and the metals to which they are applied are as follows:

Flux.	Metals to be Joined.
Rosin	Lead, tin, or tinned metals.
Tallow	Copper, iron, and lead.
Sal ammoniac	Dirty zinc, copper, and brass.
Muriatic or hydrochloric acid	Clean zinc, copper, tin, or tinned metals.
Chloride of zinc	Lead, zinc, tin tubes, and tinned metals.
Borax	Iron, steel, copper, brass, gold, and platinum.

SOLDERS TO USE FOR DIFFERENT METALS.

Material to be Soldered.	Solder to Use.
Tin	Soft, coarse or fine.
Lead	Soft, coarse.
Brass, copper, iron, and zinc	" "
Pewter	Pewterers' or fusible.
Brass	Spelter, soft.
Copper and iron	" " or hard.

To Solder Aluminum.—The solder consists of aluminum 5 parts, antimony 5 parts, and zinc 90 parts. To make it harder, use a little more antimony and a little less zinc. The following is the process of making the solder and the method of using it:

The aluminum is first melted in a pot; the zinc is then added, and when this is melted, the antimony is added. The metal is then thoroughly puddled with sal ammoniac. When the surface of the metal is quite clear and white, it should be poured into sticks ready for use, the cinders being first removed.

To make joints in aluminum with this solder, the two or more surfaces to be joined should be cleaned, either by scraping or by using acid; and the surfaces should be well coated with the solder, special care being taken that the solder penetrates into the surface of the metal without burning it. The parts to be joined should then be placed together and kept in close contact. Heat should now be applied till the solder melts, any surplus that squeezes out being wiped off.

Table showing quantity of 14″×20″ tin required to cover a given number of square feet with flat-seam tin roofing. A sheet of 14″×20″ with ½″ edges measures, when edged or folded, 13″×19″, or 247 square inches. In the following all fractional parts of a sheet are counted a full sheet.

Number of Sq. Ft.	Sheets Required.	Number of Sq. Ft.	Sheets Required.	Number of Sq. Ft.	Sheets Required.	Number of Sq. Ft.	Sheets Required.
100	59	330	193	560	327	780	455
110	65	340	199	570	333	790	461
120	70	350	205	580	339	800	467
130	76	360	210	590	344	810	473
140	82	370	216	600	350	820	479
150	88	380	222	610	356	830	484
160	94	390	228	620	362	840	490
170	100	400	234	630	368	850	496
180	105	410	240	640	374	860	502
190	111	420	245	650	379	870	508
200	117	430	251	660	385	880	514
210	123	440	257	670	391	890	519
220	129	450	263	680	397	900	525
230	135	460	269	690	403	910	531
240	140	470	275	700	409	920	537
250	146	480	280	710	414	930	543
260	152	490	286	720	420	940	549
270	158	500	292	730	426	950	554
280	164	510	298	740	432	960	560
290	170	520	304	750	438	970	566
300	175	530	309	760	444	980	572
310	181	540	315	770	449	990	578
320	187	550	321				

1000 square feet, 583 sheets. A box of 112 sheets 14″×20″ will cover approximately 192 square feet.

U. S. STANDARD GAUGE. (FOR SHEET AND PLATE IRON AND STEEL.)

(Copy.) (Public—Number 137.)

An act establishing a standard gauge for sheet and plate iron and steel.

Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled, That for the purpose of securing uniformity the following is established as the only standard gauge for sheet and plate iron and steel in the United States of America, namely:

Number of Gauge.	Thickness.		Weight.		Number of Gauge.
	Approximate Thickness in Fractions of an Inch.	Approximate Thickness in Decimal Parts of an Inch.	Weight per Square Foot in Ounces Avoirdupois.	Weight per Square Foot in Pounds Avoirdupois.	
0000000	1/2	.5	320	20	0000000
000000	15/32	.46875	300	18.75	000000
00000	7/16	.4375	280	17.5	00000
0000	13/32	.40625	260	16.25	0000
000	3/8	.375	240	15	000
00	11/32	.34375	220	13.75	00
0	5/16	.3125	200	12.5	0
1	9/32	.28125	180	11.25	1
2	17/64	.265625	170	10.625	2
3	1/4	.25	160	10	3
4	15/64	.234375	150	9.375	4
5	7/32	.21875	140	8.75	5
6	13/64	.203125	130	8.125	6
7	3/16	.1875	120	7.5	7
8	11/64	.171875	110	6.875	8
9	5/32	.15625	100	6.25	9
10	9/64	.140625	90	5.625	10
11	1/8	.125	80	5	11
12	7/64	.109375	70	4.375	12
13	3/32	.09375	60	3.75	13
14	5/64	.078125	50	3.125	14
15	9/128	.0703125	45	2.8125	15
16	1/16	.0625	40	2.5	16
17	9/160	.05625	36	2.25	17
18	1/20	.05	32	2	18
19	7/160	.04375	28	1.75	19
20	3/80	.0375	24	1.5	20
21	11/320	.034375	22	1.375	21
22	1/32	.03125	20	1.25	22
23	9/320	.028125	18	1.125	23
24	1/40	.025	16	1	24
25	7/320	.021875	14	.875	25
26	3/160	.01875	12	.75	26
27	11/640	.0171875	11	.6875	27
28	1/64	.015625	10	.625	28
29	9/640	.0140625	9	.5625	29
30	1/80	.0125	8	.5	30
31	7/640	.0109375	7	.4375	31
32	13/1280	.01015625	6½	.40625	32
33	3/320	.009375	6	.375	33
34	11/1280	.00859375	5½	.34375	34
35	5/640	.0078125	5	.3125	35
36	9/1280	.00703125	4½	.28125	36
37	17/2560	.006640625	4¼	.265625	37
38	1/160	.00625	4	.25	38

And on and after July first, eighteen hundred and ninety-three, the same and no other shall be used in determining duties and taxes levied by the United States of America on sheet and plate iron and steel. But this act shall not be construed to increase duties upon any articles which may be imported.

SEC. 2. That the Secretary of the Treasury is authorized and required to prepare suitable standards in accordance herewith.

SEC. 3. That in the practical use and application of the standard gauge hereby established a variation of two and one-half per cent either way may be allowed. Approved March 3, 1893.

TABLE OF WEIGHTS OF IRON AND STEEL SHEETING PER SQUARE FOOT. (*Kent.*)

Thickness by Stubs' or Birmingham Gauge.				Thickness by American (Brown & Sharpe's) Gauge.			
No. of Gauge.	Thickness in Inches.	Iron.	Steel.	No. of Gauge.	Thickness in Inches.	Iron.	Steel.
0000	.454	18.16	18.52	0000	.46	18.40	18.77
000	.425	17.00	17.34	000	.4096	16.38	16.71
00	.38	15.20	15.30	00	.3648	14.59	14.88
0	.34	13.60	13.87	0	.3249	13.00	13.26
1	.3	12.00	12.24	1	.2893	11.57	11.80
2	.284	11.36	11.59	2	.2576	10.30	10.51
3	.259	10.36	10.57	3	.2294	9.18	9.36
4	.238	9.52	9.71	4	.2043	8.17	8.34
5	.22	8.80	8.98	5	.1819	7.28	7.42
6	.203	8.12	8.28	6	.1620	6.48	6.61
7	.18	7.20	7.34	7	.1443	5.77	5.89
8	.165	6.60	6.73	8	.1285	5.14	5.24
9	.148	5.92	6.04	9	.1144	4.58	4.67
10	.134	5.36	5.47	10	.1019	4.08	4.16
11	.12	4.80	4.90	11	.0907	3.63	3.70
12	.109	4.36	4.45	12	.0808	3.23	3.30
13	.095	3.80	3.88	13	.0720	2.88	2.94
14	.083	3.32	3.39	14	.0641	2.56	2.62
15	.072	2.88	2.94	15	.0571	2.28	2.33
16	.065	2.60	2.65	16	.0508	2.03	2.07
17	.058	2.32	2.37	17	.0453	1.81	1.85
18	.049	1.96	2.00	18	.0403	1.61	1.64
19	.042	1.68	1.71	19	.0359	1.44	1.46
20	.035	1.40	1.43	20	.0320	1.28	1.31
21	.032	1.28	1.31	21	.0285	1.14	1.16
22	.028	1.12	1.14	22	.0253	1.01	1.03
23	.025	1.00	1.02	23	.0226	.904	.922
24	.022	.88	.898	24	.0201	.804	.820
25	.02	.80	.816	25	.0179	.716	.730
26	.018	.72	.734	26	.0159	.636	.649
27	.016	.64	.653	27	.0142	.568	.579
28	.014	.56	.571	28	.0126	.504	.514
29	.013	.52	.530	29	.0113	.452	.461
30	.012	.48	.490	30	.0100	.400	.408
31	.01	.40	.408	31	.0089	.356	.363
32	.009	.36	.367	32	.0080	.320	.326
33	.008	.32	.326	33	.0071	.284	.290
34	.007	.28	.286	34	.0063	.252	.257
35	.005	.20	.204	35	.0056	.224	.228

	Iron.	Steel.
Specific gravity	7.7	7.854
Weight per cubic foot	480	489.6
" " " inch	.2778	.2833

As there are many gauges in use differing from each other, and even the thicknesses of a certain specified gauge, as the Birmingham, are not assumed the same by all manufacturers, orders for sheets and wires should always state the weight per square foot or the thickness in thousandths of an inch.

STANDING SEAM TIN ROOFING.—Table showing quantity of $20'' \times 28''$ tin required to cover a given number of square feet with standing seam roofing. The standing seams and the locks on a steep roof require $2\frac{3}{4}''$ off the width and $\frac{3}{4}''$ off the length of the sheet; fractional parts are counted as a full sheet. A sheet will cover 475 square inches.

Number of Sq. Ft.	Sheets Required.	Number of Sq. Ft.	Sheets Required.	Number of Sq. Ft.	Sheets Required.	Number of Sq. Ft	Sheets Required.
100	31	330	100	560	173	780	237
110	34	340	103	570	176	790	240
120	37	350	106	580	182	800	243
130	40	360	109	590	185	810	246
140	43	370	112	600	184	820	249
150	46	380	115	610	135	830	252
160	49	390	118	620	188	840	255
170	52	400	122	630	191	850	258
180	55	410	125	640	194	860	261
190	58	420	128	650	197	870	264
200	61	430	131	660	200	880	267
210	64	440	134	670	203	890	270
220	67	450	137	680	206	900	273
230	70	460	140	690	207	910	276
240	73	470	143	700	212	920	279
250	76	480	147	710	215	930	282
260	79	490	149	720	218	940	285
270	82	500	152	730	221	950	288
280	85	510	158	740	224	960	291
290	88	520	161	750	228	970	294
300	91	530	164	760	231	980	297
310	94	540	167	770	234	990	300
320	97	550	170				

1000 square feet 303 sheets. A full box 112 sheets $20'' \times 28''$ will cover approximately 370 square feet.

The common sizes of tin plates are $10 \times 14''$ and multiples of that measure. The sizes most generally used are $14 \times 20''$ and $20 \times 28''$.

WEIGHT OF SHEETS PER SQUARE FOOT.

Black. United States Standard Weights.				Galvanized. National Association of Galvanized Sheet-iron Manufacturers' Weights.			
Number.	Pounds.	Number.	Pounds.	Number.	Ounces.	Number.	Ounces.
10	5.625	21	1.375	10	$92\frac{1}{2}$	21	$24\frac{1}{2}$
11	5	22	1.25	11	$82\frac{1}{2}$	22	$22\frac{1}{2}$
12	4.375	23	1.125	12	$72\frac{1}{2}$	23	$20\frac{1}{2}$
13	3.75	24	1	13	$62\frac{1}{2}$	24	$18\frac{1}{2}$
14	3.125	25	.875	14	$52\frac{1}{2}$	25	$16\frac{1}{2}$
15	2.8125	26	.75	15	$47\frac{1}{2}$	26	$14\frac{1}{2}$
16	2.5	27	.6875	16	$42\frac{1}{2}$	27	$13\frac{1}{2}$
17	2.25	28	.625	17	$38\frac{1}{2}$	28	$12\frac{1}{2}$
18	2	29	.5625	18	$34\frac{1}{2}$	29	$11\frac{1}{2}$
19	1.75	30	.5	19	$30\frac{1}{2}$	30	$10\frac{1}{2}$
20	1.50			20	$26\frac{1}{2}$		

WEIGHT OF BLACK PLATES BEFORE BEING COATED.

	IC 14×20	IC 20×28	IX 14×20	IX 20×28
Black plates before coating weigh per 112 sheets....	Lbs. 95 to 100	Lbs. 190 to 200	Lbs. 125 to 130	Lbs. 250 to 260

NET WEIGHT PER BOX TIN PLATES.

Basis 14×20, 112.

Trade term....		80-lb	85-lb	90-lb	95-lb	100-lb	IC	IXL	IX	IXX	IXXX	IXXXX
Weight per box, lbs.		80	85	90	95	100	107	128	135	155	175	195
Nearest wire-gauge No.....		33	32	31	31	30	30	28	28	27	26	25
Size of Sheets.	Sheets per Box.											
10 ×14	225	80	85	90	95	100	107	128	135	155	175	195
14 ×20	112	80	85	90	95	100	107	128	135	155	175	195
20 ×28	112	160	170	180	190	200	214	256	270	310	350	390
10 ×20	225	114	121	129	136	143	153	183	193	221	250	279
11 ×22	225	138	147	156	164	172	184	222	234	268	302	337
11½×23	225	151	161	170	179	189	202	242	255	293	331	368
12 ×12	225	82	87	93	98	103	110	132	139	159	180	201
12 ×24	112	82	87	93	98	103	110	132	139	159	180	201
13 ×13	225	97	103	109	115	121	129	154	163	187	211	235
13 ×26	112	97	103	109	115	121	129	154	163	187	211	235
14 ×14	225	112	119	126	133	140	150	179	189	217	245	273
14 ×28	112	112	119	126	133	140	150	179	189	217	245	273
15 ×15	225	129	137	145	153	161	172	206	217	249	281	313
16 ×16	225	146	155	165	174	183	196	234	247	283	320	357
17 ×17	225	165	175	186	196	206	221	264	279	320	361	403
18 ×18	112	93	98	104	110	116	124	148	156	179	202	226
19 ×19	112	103	110	116	122	129	138	165	174	200	226	251
20 ×20	112	114	121	129	136	143	153	183	193	221	250	279
21 ×21	112	126	134	142	150	158	169	202	213	244	276	307
22 ×22	112	138	147	156	164	172	184	221	234	268	302	337
23 ×23	112	151	161	170	179	189	202	242	255	293	331	368
24 ×24	112	164	175	185	195	204	220	263	278	319	360	401
26 ×26	112	193	205	217	229	241	258	309	326	374	422	471
16 ×20	112	91	97	103	109	114	122	146	154	177	200	223
14 ×31	112	124	132	140	147	155	166	198	209	240	271	302
11¼×22¾	112	73	78	82	87	91	98	...	...	...	...	...
13¼×17¾	112	67	71	76	80	84	90	...	...	...	...	...
13¼×19¼	112	73	77	82	87	91	97	...	...	...	...	...
13½×19½	112	75	80	85	89	94	100	...	...	...	...	...
13½×19¾	112	76	81	86	90	95	102	...	...	...	...	...
14 ×18¾	124	83	88	93	98	103	110	...	...	...	...	...
14 ×19¼	120	83	88	93	98	103	110	...	...	...	...	...
14 ×21	112	84	89	95	100	105	112	...	...	...	...	...
14 ×22	112	88	94	99	105	110	118	...	...	...	...	...
14 ×22¼	112	89	95	100	106	111	119	...	...	...	...	...
15½×23	112	102	108	115	121	127	136	...	...	...	...	...

TABLE OF WEIGHTS PER SQUARE FOOT OF COPPER AND BRASS SHEETS.

American or B. & S. Gauge.		Copper. Pounds.	Brass. Pounds.
Number.	Thickness.		
0000	.46 inch, or $\frac{7}{16}$ inch full	20.838	19.688
000	.40964 inch	18.557	17.533
00	.3648 " , or $\frac{3}{8}$ inch scant	16.525	15.613
0	.32486 "	14.716	13.904
1	.2893 "	13.105	12.382
2	.25763 inch, or $\frac{1}{4}$ inch full	11.670	11.027
3	.22942 "	10.392	9.819
4	.20431 "	9.255	8.745
5	.18194 " , or $\frac{3}{16}$ inch scant	8.242	7.788
6	.16202 "	7.340	6.935
7	.14428 inch	6.536	6.175
8	.12849 " , or $\frac{1}{8}$ inch full	5.821	5.499
9	.11443 "	5.183	4.898
10	.10189 "	4.616	4.361
11	.090742 "	4.110	3.884
12	.0808 inch	3.66	3.457
13	.0720 "	3.26	3.08
14	.06408 "	2.90	2.743
15	.057068 "	2.585	2.442
16	.05082 "	2.302	2.175
17	.045257 inch	2.05	1.937
18	.0403 "	1.825	1.725
19	.0359 "	1.626	1.536
20	.0320 "	1.448	1.367
21	.02846 "	1.289	1.218
22	.02535 inch	1.148	1.085
23	.02257 "	1.023	.966
24	.0211 "	.910	.860
25	.0179 "	.811	.766
26	.0159 "	.722	.682
27	.01419 inch	.643	.608
28	.01264 "	.573	.541
29	.01126 "	.510	.482
30	.01003 "	.454	.429
31	.0089 "	.404	.382
32	.0079 inch	.360	.340
33	.0071 "	.321	.303
34	.0063 "	.286	.269
35	.0056 "	.254	.240
36	.0050 "	.226	.214
37	.00445 inch	.202	.191
38	.00396 "	.180	.170
39	.00353 "	.160	.151
40	.00314 "	.142	.135

These weights are theoretically correct, but variations must be expected in practice.

TABLE OF WEIGHTS PER SQUARE FOOT OF COPPER AND BRASS SHEETS—(*Continued*).

Stubs' Gauge.		Copper. Pounds.	Brass. Pounds.
Number.	Thickness.		
0000	.464 inch, or 7/16 inch full.	20.556	19.431
000	.425 "	19.253	18.19
00	.380 ", or 3/8 inch full	17.214	16.264
0	.340 " " 11/32 " scant.	15.402	14.552
1	.300 " " 19/64 " full	13.59	12.84
2	.284 inch, or 9/32 inch full.	12.865	12.155
3	.259 " " 1/4 " "	11.733	11.09
4	.238 " " 15/64 " "	10.781	10.19
5	.220 " " 7/32 " "	9.966	9.416
6	.203 " " 13/64 " "	9.20	8.689
7	.180 inch, or 13/16 inch scant.	8.154	7.704
8	.165 " " 11/64 " "	7.475	7.062
9	.148 " " 9/64 " full	6.704	6.334
10	.134 " " 9/64 " scant.	6.070	5.735
11	.120 " " 1/8 " "	5.436	5.137
12	.109 inch, or 7/64 inch	4.938	4.667
13	.095 " " 3/32 " full	4.303	4.066
14	.083 " " 5/64 " "	3.760	3.552
15	.072 " " 5/64 " scant.	3.262	3.08
16	.065 " " 1/16 " full	2.945	2.78
17	.058 inch, or 1/16 inch scant.	2.627	2.48
18	.049 " " 3/64 " full	2.220	2.10
19	.042 " " 3/64 " scant.	1.90	1.80
20	.035 " " 1/32 " full	1.59	1.50
21	.032 " " 1/32 " scant.	1.45	1.37
22	.028 inch.	1.27	1.20
23	.025 "	1.13	1.07
24	.022 "	.997	.941
25	.020 "	.906	.856
26	.018 "	.815	.770
27	.016 inch, or 1/64 inch	.725	.685
28	.014 "	.634	.599
29	.013 "	.589	.556
30	.012 "	.544	.514
31	.010 "	.453	.428
32	.009 inch.	.408	.385
33	.008 "	.362	.342
34	.007 "	.317	.2996
35	.005 "	.227	.214
36	.004 "	.181	.171

TABLE OF WEIGHTS PER LINEAL FOOT OF BRASS AND COPPER RODS.

Inches.	Brass.		Copper.	
	Round.	Square.	Round.	Square.
	Pounds.	Pounds.	Pounds.	Pounds.
1/16	.011	.014	.01155	.0147
1/8	.045	.055	.047	.060
3/16	.100	.125	.106	.13497
1/4	.175	.225	.189	.241
5/16	.275	.350	.296	.377
3/8	.395	.510	.426	.542
7/16	.540	.690	.579	.737
1/2	.710	.905	.757	.964
9/16	.90	1.15	.958	1.22
5/8	1.10	1.40	1.182	1.51
11/16	1.35	1.72	1.431	1.82
3/4	1.66	2.05	1.703	2.17
13/16	1.85	2.40	1.998	2.54
7/8	2.15	2.75	2.318	2.95
15/16	2.48	3.15	2.660	3.39
1	2.85	3.65	3.03	3.86
1 1/16	3.20	4.08	3.42	4.35
1 1/8	3.57	4.55	3.831	4.88
1 3/16	3.97	5.08	4.269	5.44
1 1/4	4.41	5.65	4.723	6.01
1 5/16	4.86	6.22	5.21	6.63
1 3/8	5.35	6.81	5.723	7.24
1 7/16	5.85	7.45	6.255	7.97
1 1/2	6.37	8.13	6.811	8.67
1 9/16	6.92	8.83	7.39	9.41
1 5/8	7.48	9.55	7.993	10.18
1 11/16	8.05	10.27	8.45	10.73
1 3/4	8.65	11.00	9.27	11.80
1 13/16	9.29	11.82	9.76	12.43
1 7/8	9.95	12.68	10.642	13.55
1 15/16	10.58	13.50	11.11	14.15
2	11.25	14.35	12.108	15.42
2 1/8	12.78	16.27	13.668	17.42
2 1/4	14.32	18.24	15.325	19.51
2 3/8	15.96	20.32	17.075	21.74
2 1/2	17.68	22.53	18.916	24.09
2 5/8	19.50	24.83	20.856	26.56
2 3/4	21.40	27.25	22.891	29.05
2 7/8	23.39	29.78	25.019	31.86
3	25.47	32.43	27.243	34.69
3 1/4	30.45	38.77	31.972	40.71
3 1/2	35.31	44.96	37.081	47.22
4	46.124	58.73	48.433	61.67

To find the weight of octagon rod, take the weight of round rod of a given size and multiply by 1.084.

To find the weight of hexagon rod, take the weight of round rod of a given size and multiply by 1.12.

These tables are theoretically correct, but variations must be expected in practice.

Painting.—MATERIALS.—The most common materials used for mixing paints are linseed-oil, turpentine and benzine, and zinc white. Generally speaking, and with many exceptions of course, two or more of these substances in combination, with varying proportions of the several colors, constitute the house-painting materials on the market.

Linseed-oil.—Linseed-oil is pressed from the seeds of the flax plant, and after purification becomes the raw oil of commerce. After being heated in connection with certain oxidizing agents (driers) such as red lead, litharge, manganese oxide, manganese borate, etc., either by means of direct fire or in a steam-jacketed kettle, it is known as boiled oil.

The peculiar quality of linseed-oil to absorb oxygen from the air, and in oxidizing to form a tough, elastic substance, known as linoxyn (a property which it possesses in common with a few other so-called drying oils—poppy-oil, nut-oil, etc.), gives it special value in paint- and varnish-making. Any admixture with mineral oils or non-drying vegetable oils greatly impairs or wholly destroys this value, so that for painting purposes it is most essential to know that the oil employed is absolutely pure.

Good raw linseed-oil is pale in color and transparent, has very little odor and is sweet to the taste. If it is dark in color and dries very slowly it indicates an inferior oil. Linseed-oil should have an age of six months before being used, and more age improves it. Raw oil spread on a glass should dry in from two to three days, according to the state of the weather.

Boiled Oil.—Boiled linseed-oil, commonly called boiled oil, is prepared by heating the raw oil with certain driers. By this process the drying qualities of the oil are greatly improved; the drying qualities of raw oil are also improved by simply boiling it, but when such substances are added as mentioned below, this improvement is greatly enhanced. Dark drying oil may be made of these ingredients: To 1 gallon of raw oil add 1 pound of red lead, 1 pound of umber, and 1 pound of litharge.

The oil is heated to about 200° F. When it looks brown and the scum is burned off, the substances mentioned are added; the whole is then brought up to about 400° F., and for two or three hours kept at that temperature. The oil is then drawn

off and the albuminous matter allowed to deposit, after which it is ready for use. The umber is added simply to give the oil a dark color.

Pale drying oil may be made by mixing 7 pounds of litharge or acetate of lead to each gallon of oil and raising to a moderate temperature.

For common work, drying oil can be made by adding 1½ pounds of red lead to a gallon of oil and allowing the mixture to settle after having been boiled.

Boiled oil is much thicker and darker in color that the raw oil. When spread on a glass in a thin film it should dry in from twelve to twenty-four hours, depending on the condition of the weather.

Raw oil is used for interior work and for grinding colors; the boiled oil is used for outside work and is not suited for grinding. For outside work the boiled oil gives the paint a much more glossy finish than the raw oil, for when the raw oil is used, a liquid or other drier must be added, and this takes away the lustre from the oil.

The bung-hole process, so-called, is the simple injection of manganese drier into a barrel of raw linseed at proper temperature.

Raw oil in which a certain percentage of liquid japan drier has been mixed is often sold as boiled oil.

Fish-oil, cottonseed-oil, and vegetable oils are often substituted for boiled oils.

Linseed-oil to which turpentine has been added (in small quantity) dries more rapidly than without the turpentine because it spreads over more surface, being thinner, and so comes in contact with a larger body of air, which dries it in the diluted state faster.

Turpentine is not a drier, simply a thinner.

Linseed-oil is often adulterated by adding fish, hemp, cottonseed, resin, and mineral oils. These adulterations are hard to detect except by chemical analysis; they change the odor somewhat and the specific gravity.

The superintendent should always keep himself in possession of a sample of both the raw and boiled oils which he knows to be pure, and with which he can compare any oils which may be used under his supervision.

Good linseed-oil should be of a light straw color, weigh 7½ pounds to the gallon, boil at 130° C. (260° F.), solidify at 27° C.

(17° F.), and have a specific gravity at 15° C. (60° F.) of 20° Baumé (0.932).

To test for the presence of fish-oil, shake equal parts of oil and strong nitric acid in a small glass vial and let it stand fifteen to thirty minutes. In pure linseed-oil the upper stratum will be olive-green, which gradually changes to a brown, and the lower stratum will be almost colorless; if fish-oil is present, the upper stratum will be of a deep red brown and the lower stratum will be deep red or cherry-red. If only a small amount of fish-oil is present, the color of the lower stratum may gradually disappear until it becomes almost colorless.

To test for petroleum, shake the oil with concentrated solution of potash or soda containing a little grain alcohol and then add a little warm water and shake again. Let it stand for about thirty minutes, and if any petroleum is present it will separate and float on top.

To test for cottonseed-oil, put samples of the oil in tubes and place them in a freezing mixturesuch as ice or snow and salt. If the mixture solidifies at 0° or 10° to 13° F., then cottonseed-oil is probably present, as pure linseed-oil solidifies at 17° F.

Hydrometer Tests.—First test the specific gravity of an oil known to be pure, and then test the doubtful oil at the same temperature.

Twenty-five per cent of cottonseed-oil will make a difference of 1° Baumé less than pure linseed-oil at the same temperature.

Ten per cent of petroleum will make a difference of $\frac{3}{4}$° less and 20 per cent will make a difference of $1\frac{1}{2}$° less at the same temperature.

The quality of linseed-oil may be determined by looking through a vial filled with it and turned towards the light. If poor in quality, the oil tends towards opacity, appears turbid or milky, while its taste is strong and rancid.

Turpentine.—Spirits of turpentine is a volatile oil, obtained by distilling with water, in an ordinary copper still, turpentine previously melted and strained. The distilled product is colorless, limpid, very fluid, and has a peculiar smell. The residuum left after distillation is called resin.

The ordinary use of spirits of turpentine is to thin oil paints, to flatten white and other colors, or to remove superfluous color in graining. It prevents paint, however, from bearing

out, and when used alone will not fix the paint on the surface to which it is applied.

Good turpentine is colorless and has a pleasant pungent odor; if adulterated or of an inferior quality it will have a disagreeable odor.

When evaporated good turpentine should have a very slight residue, and when spread on a glass in a thin film should dry in twelve to twenty-four hours.

Turpentine is often adulterated with mineral oils. The pure turpentine loses bulk by evaporation and gains weight upon exposure to the air. Adulterated with mineral oils, the spirit evaporates, leaving the oil without any assistance in hardening.

Turpentine containing such oils will usually leave a greasy stain on white paper, a drop of it on a watch-crystal will reflect prismatic colors in the direct rays of the sun, and the hydrometer will stand in such a mixture above 32°.

But little if any turpentine should be used on good work. The result of the use of turpentine is that the proportion of oil is reduced. This enables the painter to conceal the painted surface with fewer coats than would otherwise suffice. Turpentine also hastens the drying of the paint by reducing the quantity of the oil, and the turpentine itself possessing some oxidizing or drying properties.

Good turpentine should be crystal-clear and water-white, weigh 7 pounds to the gallon, boil at 160° to 165° C. (320° to 340° F.), and have a specific gravity at 15° C. (59° F.) of 31° Baumé hydrometer (0.870).

The presence of benzine or naphtha in turpentine can usually be detected by the odor; with the hydrometer test 5 per cent of this adulterant will make a difference of 1½° Baumé.

The presence of petroleum can usually be detected by the delicate "bluish bloom" or smoky bluish-yellow cloud it imparts to the turpentine.

To detect small quantities of petroleum, fill two white glass vials, one with the doubtful article and one with turpentine known to be pure; hold both over a piece of black paper and look directly down into the liquid; 3 to 5 per cent of petroleum will impart a decided bloom or cloud to the "turps." With the hydrometer test 5 per cent of petroleum will make a difference of ½° Baumé.

Pure	turpentine	at	15° C.	(59° F.)	is	31°	Baumé	hydrometer.
5%	benzine	"	"	"	"	$32\frac{1}{2}$°	"	"
15%	"	"	"	"	"	34°	"	"
25%	"	"	"	"	"	38°	"	"
5%	petroleum	"	"	"	"	$31\frac{1}{2}$°	"	"
10%	"	"	"	"	"	32°	"	"
25%	"	"	"	"	"	34°	"	"
$33\frac{1}{3}$%	"	"	"	"	"	$35\frac{1}{2}$°	"	"

White Lead.—The discovery of white lead is lost in the mists of antiquity. It has been a familiar painting material for many centuries, and the earliest recorded method of production differed only in detail from that generally practised at the present day. In most European and American factories the method used is that known as the "Old Dutch" process of corrosion. The chief exceptions are the single plant in France producing the celebrated *Ceruse de Clichy;* the few German factories producing "Kremnitz white" by dry precipitation; the one plant in England producing the celebrated Pattison white lead by wet precipitation; and the two equally famous plants of the Carter White Lead Company in this country, practising corrosion by a controllable chemical process acting on the lead in a finely comminuted form, the last named being merely a technical modification of the older process, shortening the time required for completion.

The old Dutch process of corrosion is in outline as follows: The pig or metallic lead is melted and cast into perforated disks, called buckles, about 6 inches in diameter, which are put into pots containing each about one pint of dilute vinegar. These are placed in rooms holding several layers, or tiers, 600 to 1000 pots each. The pots are covered with boards and layers of tanbark, placed between each tier. The rooms, technically called beds, are kept closed from three to four months. During this period the heat and the carbonic-acid gas generated by fermentation of the tan, together with the acid vapors, combine to corrode the lead into a white flaky substance.

This, after it is crushed, screened, ground in water and dried, forms the white lead of commerce, and is either sold in the dry state to mixed paint and color manufacturers or ground in linseed-oil and sold for general painting purposes.

White lead thus produced is a compound of lead hydroxide

and lead carbonate, generally retaining a residue of acetic acid and more or less water. It is exceedingly variable in composition, nearly every sample analyzed showing different proportions of the constituent components. Thus in four analyses reported by Prof. Hurst the proportion of carbonate ranged from 63.35 per cent to 72.15 per cent; that of the hydroxide from 25.19 to 36.14; and that of the moisture from 0.42 to nothing. Prof. Church gives the ideal proportion as 70 per cent of the carbonate to 30 per cent of the hydrate, but this exact proportion is very rarely attained in practice. Five different American brands of pure old Dutch process white lead analyzed a few years since by Mr. Convers proved to be constituted as follows:

	I.	II.	III.	IV.	V.
Lead carbonate	85.32	79.37	78.58	77.98	69.96
Lead hydrate......	14.83	19.80	20.11	20.60	30.19
Lead oxide........	....	....	1.48	1.48	....
Water.............	.03	.21	....	....	.07

The samples analyzed were dry leads and not the product in oil as sold to the consumer. The latter, especially when mixed without drying, as in the pulp process, will generally show a higher percentage of moisture, while acetic acid and uncorroded particles of lead, left by imperfect grinding and washing, are not rare; Church reports as high as 11 per cent of lead acetate in flake white.

This, the ordinary white lead of commerce, is a heavy, opaque material, ranging in color from yellowish white (cream color) to grayish white; indeed, it seldom happens that two separate corrosions yield precisely the same shade of tone. This variation is, of course, unimportant, except in attempting to match shades by the addition of definite proportions of color.

Precipitated white lead is made by suspending rolls of thin sheet lead or small bars over malt vinegar or pyroligneous acid in closed vessels, the evaporation of the acid being kept up by heat applied to the vessels while immersed in a steam bath. The white lead produced by precipitation is generally considered inferior to that prepared by corrosion, wanting, as it is, in density or body, and when mixed with its vehicle, absorbing too much oil.

Sublimed Lead is obtained as a by-product in the smelting

of lead ores. The products of this smelting are pig lead, slags poor enough in lead to be thrown away, and the "fume," which is white and in a fine state of subdivision, suitable for a white pigment, and is sold as such either dry or ground in oil. It is known to the trade as Joplin lead, being manufactured first at Joplin, Mo., or as Picher lead, from the name of the company manufacturing it.

Adulterations.—White lead may be either pure or mixed with various substances, such as sulphate of baryta, sulphate of lead, sulphate of lime, whiting, chalk, zinc white, etc.; these substances do not combine so well with oil as does white lead, nor do they so well protect the surfaces to which they are applied.

Sulphate of baryta, the most common adulterant, is a dense, heavy, white substance, very much like white lead in appearance. It absorbs very little oil, and can usually be detected by the gritty feeling produced when the paint is rubbed between the fingers.

Pure white lead is insoluble in water, effervesces with dilute hydrochloric acid, dissolving when heated, and is easily soluble in dilute nitric acid. When heated on a piece of glass the white lead becomes yellow.

To test dry lead, digest a small quantity with nitric acid, in which it dissolves readily on boiling. When ground with oil, the oil should be burned off and the residue treated with nitric acid; or the white lead ground with oil may be boiled for some time with strong nitric acid, which destroys the oil and dissolves the lead on the addition of water. If sulphate of baryta be present, it being insoluble in the acid, it remains behind and can be collected on a filter, washed with hot distilled water, and weighed.

The presence of other adulterants may be detected by the change in the specific gravity of the lead when dry, or by various methods of analysis.

Zinc White.—Zinc white is hydrated zinc carbonate or oxide. It is perfectly durable in oil and water, but wanting in body. For inside work, zinc is preferable to white lead, and for outside work, about 25 per cent of zinc in the lead color makes a better paint than the pure lead. For use in its pure state, zinc white should be finely ground in refined linseed-oil with the proper proportions of manganese drier, and if for interior use, should have a small proportion of good white varnish.

In painting in pure zinc, the first coat may be tinted with black, over which the second coat will make a perfect covering.

A soft brush with long hairs should be used, brushing lightly, and the paint should be applied a little thicker than a lead paint.

The purity of zinc may be determined by washing out the oil with benzine and dissolving the pigment in sulphuric acid. Any residue shows the presence of other pigments. On a painted surface the presence of lead can be determined by scratching a spot through the paint and applying a drop of sodium sulphide of 100° Baumé. If lead be present it will cause a decided discoloration.

Red Lead (Red Oxide of Lead).—This is one of the oldest pigments, formerly known as minium or saturnine red. It is a deuoxide of lead prepared by subjecting massicot to the heat of a furnace, with an expanded surface and free accession of air.

Red lead is often adulterated with red oxide of iron, brick-dust, or mineral paints. To test, heat the red lead and treat with dilute nitric acid; the red lead will be dissolved and the adulterants remain. Boiling hydrochloric acid extracts the sesquioxide of iron from the residue.

Oxide of Iron is produced from the brown hematic ores; the ore is roasted and separated from impurities and then ground.

Antimony Vermilion (Sulphide of Antimony) is produced from antimony ore. It is sometimes used as a substitute for red lead.

Vermilion is a sulphuret of mercury, which previous to its being levigated is called cinnabar. Vermilion is adulterated with red lead, brightened with eosine, and with logwood mixed with molasses. Powder vermilion may be tested by placing a small quantity on a piece of paper laid on a hard surface; cover this with a card or other piece of paper, which rub with the thumb-nail or smooth handle of a penknife. If the vermilion be pure, it will on the removal of the paper present a smooth surface of the uniform original color, but if adulterated with red lead, etc., it will appear orange or yellow.

Indian Red is ground hematite ore or peroxide of iron, but can be made artificially by calcining sulphate of iron. It is sometimes called Persian red.

Scarlet Red.—A name given to a very bright scarlet shade of iron-oxide pigments.

Venetian Red.—A red pigment made by heating ochres. Light-red color works well in oil or water. This red is not only useful as a solid color of extreme permanence, but the tints are clean and sharp even when reduced to a delicate rose tint. Many common Venetian reds are made in a crude manner with a cheap, coarse base.

Oxide.—Oxide reds are noted for their permanency and durability. They owe their color to ferric oxide by the precipitation of iron solutions.

Lakes.—A class of pigments of ancient origin, made extensively of cochineal, combined with tin and alumina. Florentine lake, Dutch pink, and rose pink contain an excess of metallic base in their composition.

YELLOWS.—*Chrome Yellow* is obtained from the subchromate of lead. Frequently adulterated with gypsum, it is prepared by mixing diluted solutions of acetate or nitrate of lead and bichromate of potash.

Naples Yellow.—This old and well-known pigment is a compound of the oxides of lead and antimony. This pigment is generally replaced by chrome yellows.

King's Yellow, the least durable of the yellow pigments, is obtained from arsenic. It is sometimes called Chinese yellow and should never be used for good painting.

OCHRES.—A most important group of natural pigments found in many places. The depth of color is variable; in some it is strong, in others weak.

Yellow Ochre is a natural clay, colored by oxide of iron. It varies in color from yellow to brown.

Raw Sienna appears to be an iron ore, considered as a crude natural yellow lake.

Dutch Pink.—Strange to say a yellow lake should be called Dutch pink, still such is the case.

This pigment is a yellow lake prepared from Persian berries by precipitating with alum and whiting.

BLACK PIGMENTS.—*Lampblack* is simply the soot obtained by burning resinous woods, tallow, coal-tar, oil, bituminous coal, etc. It is a purely carbonaceous substance of fine texture and very durable.

Ivory-black is obtained by calcining or charring to blackness in a closed vessel waste ivory and then grinding. This makes a superior black, but is more expensive than the others.

Bone-black is prepared from bones by a similar process to ivory-black, using bones as the raw material. It has a reddish tint, and unless well burned tends toward a brown color.

Frankfort or Vegetable Black is a pigment prepared from the sediment of wine, vine twigs, and tendrils from which the tartar has been washed, by burning in the same manner as ivory-black. It is used mostly by printers.

Blue Black is a well-burned and levigated charcoal of a cool neutral color, very much like the Frankfort black.

BLUE PIGMENTS.—*Prussian Blue* is made by mixing prussiate of potash with a salt of iron. The prussiate of potash is obtained by calcining and digesting old leather, blood, hoofs, or other animal matter with carbonate of potash and iron filings.

Indigo Blue is a pigment manufactured in the East and West Indies from several plants, but principally from the anil, or indigofera. It is very inferior to Prussian blue.

Cobalt Blue is an oxide of cobalt made by roasting cobalt ore.

Blue Lead is obtained by subliming lead similar to the process used for making sublimed white lead.

Ultramarine Blue.—Ultramarine is one of the most important blue pigments at the disposal of the painter. The ultramarine of commerce is largely made artificially by furnacing a mixture of silica, china clay, sulphur, soda, sodium sulphate, and rosin, these ingredients being mixed together in various portions according to the character of the ultramarine desired. Several qualities of ultramarine are made, varying in depth of tone, tint, fineness, and other qualities.

Ultramarine is a blue pigment of exceedingly bright character, varying from a pale greenish blue to a violet-blue. It is extensively used in water painting, distemper, fresco-work, printing of all kinds, and laundry purposes. When exposed to all ordinary atmospheric conditions it is quite permanent, which is a most important feature of ultramarine. It is easily affected when treated with acids, as the color is destroyed, although it is unaffected by boiling with alkaline solutions of any kind. Some varieties of ultramarine are reddened in tone by being mixed with a solution of alum or alumina sulphate.

The use of even the most carefully selected ultramarine with white lead is not to be recommended, as it is a sulphur compound and liable to blacken the lead.

Prussian blue is without this defect, having no sulphur in it.

Bremen Blue.—Bremen blue is a basic carbonate of copper, soluble in acids; on adding ammonia a deep-blue solution is obtained, a reaction which is highly characteristic of copper.

GREEN.—*Chrome Green.*—An oxide of the metal chromium, and usually made by fusing together bichromate of potash and boracic acid. It is the most permanent green known, very bright, not acted on by acids, heat, or alkalies.

Greens known by various trade names are produced by treating the acetate or carbonate of copper with sal ammoniac. Greens are also made from the arsenites of copper, and from cobalt and ferrous oxide of zinc.

BROWN.—Umber is the name of a brown pigment obtained through the agency of oxide of iron from naturally colored clays, some coming from Turkey, and some from Umbria, in Italy, from which it derives its name. When in its natural state it is called raw umber, but after being calcined at a low temperature it is called burnt umber.

Raw Sienna is a clay stained with oxides of iron and manganese. It was originally found in Sienna, Italy. Siennas differ from ochres in being rather more transparent, making them very serviceable in staining properties.

Burnt Sienna is of a bright orange-red color, permanent in color and mixes well with oil and water.

Vandyke Brown.—A natural earth of warm brown color resembling the umbers, works well in oil or water, and is permanent.

COMPOUND COLORS.—In mixing different colored paints to produce any desired tint, it is best to have the principal ingredient thick and add to it the other colors thinner. In the following list of the combinations of colors required to produce a required tint, the first-named color is the principal ingredient and the others follow in the order of their importance:

Buff—white, yellow ochre, red.

Chestnut—red, black, yellow.

Chocolate—raw umber, red, black.

Claret—red, umber, black.

Copper—red, yellow, black.

Dove—white, vermilion, blue, yellow.

Drab—white, yellow ochre, red, black.

Fawn—white, yellow, red.

Flesh—white, yellow ochre, vermillion.

Freestone—red, black, yellow ochre, white.

French gray—white, Prussian blue, lake.
Gray—white lead, black.
Gold—white, stone ochre, red.
Green bronze—chrome, green, black, yellow.
Green pea—white, chrome green.
Lemon—white, chrome yellow.
Limestone—white, yellow ochre, black, red.
Olive—yellow, blue, black, white.
Orange—yellow, red.
Peach—white, vermilion.
Pearl—white, black, blue.
Pink—white, vermilion, lake.
Purple—violet, with more red and white.
Rose—white, madder lake.
Sandstone—white, yellow ochre, black, red.
Snuff—yellow, Vandyke brown.
Violet—red, blue, white.

The following table gives the proportions of colors for some of the most common colors:

Colors.	Ingredients by Weight.						
	White Lead.	Lamp-black.	Red Lead.	Red Ochre.	Verdi-gris.	Burnt Umber.	Spanish Brown or Raw Umber.
White	100	...	...	...	...	...	....
Black	...	100	...	...	...	...	....
Green	25	...	...	...	75	...	....
Stone	99	...	...	...	...	1	....
Lead	98	2	...	...	...	...	....
Red	...	...	50	50	...	...	....
Chocolate	...	4	...	...	...	...	96

Preparing for and Applying Paints.—In preparing work for painting too much care cannot be exercised, as succeeding coats and the final result depend very much on the proper condition of the work when the priming coat is applied.

First, all the rough places in the wood should be rubbed down with a block covered with sandpaper and all mouldings cleaned out with the same. Then every knot, however small, every indication of sap-wood or discoloration of any kind, and every appearance of pitch or gum, should be carefully covered with a coat of shellac. If the work is to be finished in a light color, or if it is inside work, white shellac should be used.

When the work is to be finished in two coats, the putty used for stopping the nail-holes and other indentations should be made of white lead, worked up with whiting to the proper consistency, and the filling should be done after the first coat has become well dried. When more than two coats are to be put on, the filling or putty should be used between the first and second coat, and ordinary linseed-oil putty should be used.

As a rule white should never be used as a priming coat; no matter how many coats are to be put on the result will be more satisfactory if the first coat be darkened a little with lampblack.

The way to produce solid, uniform work is by making every succeeding coat a little lighter in color than the one preceding it.

It is well to use for priming the same color as the work is to be finished; if it is to be finished green, use green for priming, or if to be finished blue, let blue be the groundwork. All work should be primed, especially with regard to the finishing color.

The paint should be put on by strokes parallel to the grain of the wood; and long smooth pieces, such as window- and door-casings, should be finished by drawing the brush the full length, so that there will be no breaks or brush-marks. The brush must always be at right angles to the surface being painted, and only the ends of the hairs touching it; in this way the paint is spread evenly and forced into the pores of the wood. No paint should be put on top of a preceding coat unless it is perfectly dry and hard.

When paint is applied to walls and ceilings the plaster must be perfectly dry and free from all moisture.

Paint for exterior work should be mixed with boiled linseed-oil.

Painting Tinwork.—Before painting tin, all surplus resin, grease, or oil must be carefully removed. If necessary the surface should be washed with benzine. Red lead is usually used for painting tin. It should be composed of 15 pounds red lead to 1 gallon of linseed-oil. Tinwork should be painted as soon as possible after being put in place, and if any rust shows it should be carefully removed.

Painting Ironwork.—Before painting wrought iron or steel care must be taken to have all scales, grease, rust, etc., removed. The scales can be taken off by brushing with a stiff wire brush,

and the rust can be removed by scraping with steel scrapers, or by a sand-blast, or by pickling in diluted acid, which is washed off with water. All indications of rust should be removed before any paint is put on, for a small spot of rust may grow under the paint and in time cause a flake of the paint to scale off. Deep rust can be burned off with a gasoline torch; the heat converts the rust into peroxide of iron, which can be dusted off. When red lead is used for painting iron or steel it should be composed of 25 pounds of lead to 1 gallon of oil. It will require the close attention of the superintendent to have it put on this thick, for it is hard to spread, but when it is mixed thin it will run and the lead will settle to the lower part of the iron, leaving just a coat of oil.

When any interior painting is being done, all windows should be covered to keep the paint off the glass; a little precaution at this time will save lots of work in the future.

Cleaning Old Paint.—This may be effected by washing it with a solution of pearlash in water. If the surface is greasy, it should be treated with fresh quicklime mixed in water, washed off and reapplied until the grease is entirely removed.

Removing Old Paint.—Dissolve 2 ounces of soft soap and 4 ounces of potash in boiling water; add ½ pound of quicklime; apply hot and leave from twelve to twenty-four hours. This will enable the old paint to be washed off with hot water.

VARNISHES.—Varnish is a solution of certain gums or resins in alcohol, turpentine, linseed-oil, or the like, and is applied to produce a hard shining transparent coat on the surface.

To estimate the quality of a varnish, the following points are to be considered: (1) Quickness in drying; (2) hardness of film or coating; (3) toughness of film; (4) amount of gloss; (5) permanence of gloss; (6) durability on exposure to weather.

Varnish Gums.—Under the names of copal and damar various gums in the form of resins which are found in various parts of the world are employed in the manufacture of varnishes. The typical copal comes from the west coast of Africa, and is found as a fossil in the river-beds and soft ground of the district. The gathering is done during the wet season, when the ground is sufficiently soft to permit of its being dug into by negroes, who use such primitive tools that they are ineffective in dry season. The botanical origin of copal is unknown. Some authorities assign it to a tree, now extinct, along the coast. Copal from this section comes in rough angular pieces

covered with a crust of disintegrated resin; when scraped off the resin is found lustrous, quite transparent, and almost colorless. It melts at 400° F. When powdered about 33⅓ per cent after long digestion will dissolve in ether, while the rest simply swells up. When melted it gives off a small proportion of an oily liquid which contains a terpene; the residue on cooling will set into a hard, brittle mass soluble in ether, turpentine, or chloroform, etc. It is on this property of becoming soluble after being fused that the manufacture of varnishes from copals is based, and from which the best class of carriage and cabinetmakers' varnishes are made.

The Singapore damar is generally considered the true damar, from the Amboyna pine tree, exuded out of certain excrescences which grow a little above the root of the tree. In Java and Sumatra the resin is allowed to flow out naturally; in some localities natives make incisions to promote the flow. The Singapore damar comes in form of rounded pieces with powdery crust, transparent and quite brittle. It is soluble in turpentine, ether, chloroform, etc. Damar produces a varnish which is pale, lustrous, and dries with a very hard coat. Varnishes requiring a clear, light, brilliant, lustrous finish are made from the best damar.

A great variety of varnish gums are also employed in the manufacture of varnish, although the above described are considered the best of their class.

Much care must be exercised in applying varnish to get it spread on evenly; a fine hair-brush must be used and the varnish well spread out, but not worked enough to make it froth or foam; it must be worked out thin enough so that it will not run, and no succeeding coat of varnish should be put on until the preceding coat is hard and dry. Each coat of varnish should be well sandpapered before another one is put on.

Good varnish should dry and be free from stickiness in from one to two days.

The more oil a varnish contains the less liable it is to crack.

One pint of varnish will single coat about 14 square yards.

Finishing of California Redwood.—California redwood is being more generally used for inside finish every year, and on account of its peculiarities in regard to finishing and varnishing, the following directions are given, which if followed will produce the best results.

Formula for Finishing Redwood: Shellac Finish.—First give one coat of orange-gum shellac (which is a good quality of gum shellac and alcohol), applied very thin. If more color is required, give another coat of orange shellac, waiting at least twenty-four hours after giving the first coat. Take No. 1 sandpaper and work the raised grain, caused by shellacking down to a surface; then give one coat of white shellac. Let this coat be heavy and stand twenty-four hours to harden; if you finish quicker than this the whole is liable to crack. Then rub with curled hair or haircloth until the gloss is taken off. Then apply another coat of white shellac a little thinner. Let stand two days and rub with curled hair or haircloth same as first coat; then apply a third coat of white shellac same as second, and let stand two days; rub down to a surface with No. 00 pulverized pumice-stone, felt, and water, being careful not to rub through the varnish on the corners; clean off thoroughly dry with chamois skin; then take pulverized rottenstone and water and a piece of dry felt and rub the work thoroughly with the same; clean off with water and dry with chamois skin, or instead of cleaning off the rottenstone with water and drying with chamois skin, take the palm of the hand and rub the rottenstone until it is dry, which will bring it to a fine gloss (but to finish in this latter way the finisher's hand must be perfectly soft and free from dust or grit), and take a soft cloth and wipe the hands off often, because if the least bit of grit accumulates it mars the work; then take raw linseed-oil, a little fine cotton batting, and rub work over thoroughly, and take a piece of dry soft cotton cloth and wipe it off.

To do better work, rub with pumice-stone between every other coat of shellac, and the more times rubbed and shellacked, the finer the work turned out, or, in other words, by finishing the wood smooth to commence with, and putting on five to seven coats of shellac and rubbing between every other coat, the finest piano finish can be obtained.

To finish a DEAD finish, use no rottenstone, but instead rub in pulverized pumice-stone and water, clean off thoroughly, and oil off with raw linseed-oil.

To give redwood a bright, rich color, take the following: One-fourth pound dry Venetian red and put in two quarts of turpentine, stir up and let settle; then use the turpentine, which will be colored a very little. Apply this for first coat.

Other formulas for finishing are used to a great extent. For instance, many use last coats of rubbing varnish, because it is softer to work and polishes easier, but where they are used none but the best grades are desirable; also all good grades of rubbing varnish take from five to thirty days to dry each coat. The quick-drying grades have more or less resin in them and scratch white.

Shellac, being very hard, is, of course, more expensive to rub down, but the firmness is a protection to the wood, and it is known to be the most durable finish for any kind of wood.

Never buy prepared shellac, but buy the gum shellac and alcohol and cut it, as most prepared shellac is cut with cheaper ingredients than alcohol, and oftentimes spoils what otherwise would have been a nice finish.

Use it quickly, so as not to show laps, as it dries fast.

Varnish Finish.—Use only good grades of varnish, which will cost at least $2.50 per gallon, and for fine work even better grades should be used. A gallon of varnish covers so much surface it hardly pays to use anything cheaper than $3 varnish in good work. First coat should be applied very thin—about one-half turpentine and one-half varnish. Other coats can be used full strength. This will insure good color and will improve with age. Any amount of rubbing can be done that is desired, but three-coat work, with sandpaper after first coat and rubbing after last coat, makes *good* work for house finish.

Wax Finish.—Use beeswax cut with turpentine until as thin as linseed-oil; apply with brush. Second coat use as thick as lobbered milk. Apply with soft cloth and rub till dry; the more rubbed the better it will look. This will not show much finish at first, but in a few months the wood will gradually grow richer in color, and one of the most pleasing and restful effects to the eye is obtained. It produces what is called a dead finish. This does not scratch white, and if bruised at any time can be easily repaired with a little of the last coat, and should it grow dusky or too dull looking with age can be brightened up like new by rubbing with soft cloth wrung out of warm water.

Front Doors and Exterior Work.—For front doors and exterior work use only the *best coach varnish*, which is made from gums that will stand 550 degrees of heat before melting. This is the only thing that will stand the hot rays of the sun. Use no shellac with this.

Formula for Removing Dark Stains from Redwood: Use Crystallized Oxalic Acid.—Put in a bottle, pour water over it, and let dissolve. There is no danger of getting the solution too strong, as the water will take up only a certain portion of the acid. By wetting a cloth with this solution all stains can be rubbed off.

Caution.—Bottles should be marked "Poison." In using be careful that there are no sores on the hands.

Fillers.—Fillers should never be used in redwood, as most of them contain linseed-oil, which will spoil the work.

Caution.—Never use anything next to the wood that contain linseed-oil, as the acid in the wood seems to turn the oil into a sort of soapy condition that destroys all the fine lustre of the grain.

SHELLAC.—Lac is a resinous secretion found surrounding the twigs and branches of several trees in India and neighboring districts. The secretion is formed from the sap of trees, which sap is of a gummy and resinous nature, by the female of the lac insect, coccus lacca. The insect punctures the bark of the tree and commences to secrete the lac, in which it soon becomes completely enveloped; it then lays its eggs inside the deposit of lac and then dies. The young insects when they are born bore their way through the lac and swarm over the branches of the tree.

Shellac is the principal commercial variety of lac and is prepared and sold in large quantities. It is prepared from the seed lac by drying the latter product. The dried lac is then placed in large bags made of cotton cloth of medium texture.

The bag of lac is held by two men in front of a large fire. The heat of the fire soon melts the lac, which flows out of the bag, the men assisting the flow by twisting the bag so as to squeeze out the contents; the molten lac drops into a trough placed in front of the fire.

A cylinder of wood covered with brass is mounted on axles so as to be in a slightly inclined position; an operator dips a ladle into the trough of lac and pours it over the surface of the cylinder with a platen leaf. It rapidly sets, when it is stripped off the cylinder by means of a knife and is ready for the market. The best quality of shellac is known as orange shellac, which is a pale brownish orange color, but quite transparent.

White shellac is obtained through the method of bleaching orange shellac with oxalic acid, etc.

PUMICE.—Pumice, as is well known, is of volcanic origin, being a trachytic lava which has been rendered light by the escape of gases when in the molten state. The best stone is almost exclusively obtained from Monte Chirica, on the little island of Lipari, off the coast of Italy. The stone is brought to the surface of two great craters of extinct volcanoes in blocks or baskets by the natives, of whom about 1000 are employed in the industry. The supply is said to be practically inexhaustible.

Pumice is not merely used for scouring and cleaning purposes, but also for polishing and rubbing down between coats on finishing work for coaches, carriages, and interior woodwork. It is also used for wood filler.

ROSIN.—When the resinous exudations from various species of pine-trees are distilled with the aid of steam the products are a volatile spiritous substance, turpentine, leaving a liquid residue which, when cold, forms a hard, solid mass, known as rosin. Rosin is translucent and amber-colored, brittle, and melts at 212° Fahr.; at a higher temperature it decomposes into water, spirit, and oil.

Rosin is soluble in water, alcohol, turpentine, ether, benzine, and petroleum spirit. It is largely used in the preparation of cheap varnishes; such varnishes, however, do not possess the durability characteristic of copal or kauri varnishes.

Filling Hardwoods.—Oak, chestnut, ash, and all woods with large pores must have a coat of filler before being varnished, and unless the filler is well rubbed into all the pores and all the cavities are filled level with the surface of the wood, a satisfactory job of varnishing cannot be obtained. The superintendent should pay close attention to the work as it is being filled, so as to get a perfect surface to apply the varnish to.

The essential parts of a hardwood filler are a transparent, non-absorbent, mineral base and a proper proportion of linseed-oil and japan to make a good binder.

Transparent, for the reason that when cleaned off the lights or growths of wood must show up clear. China clay, whiting, paris white are not good, as they are all opaque; a filler made with such a base leaves a clouded, muddy appearance that is

particularly objectionable to the present style of antique oak, the market requiring the greatest possible contrast between the growth and the pore.

Non-absorbent, because the sole purpose of a filler is to bear the varnish up over the pore equally as bold as it is over the growth, thus producing an even surface on which to rub or polish Such absorbents as powdered pumice-stone, etc., absolutely fail to produce the required result.

Mineral as a mineral is unshrinkable. Corn-starch and all other vegetable matter shrink with time; the varnish drops with it, leaving a depression at each pore.

Pinholes.—Failure to rub the filler well into the pore produces pinholes, or, more properly speaking, blow-holes. These are more often found in second-growth straight-grained oak, that possessing a deeper pore than most other wood; they are caused by the filler being wiped off instead of rubbed in, and thereby forced to the very bottom of the pore, thus driving out all the air. Failure to get rid of the air in the pore means that as the filler dries it gradually sags down, compressing the air to such a degree that it blows its way out, making a pinhole that is there to stay. Any number of coats that may be applied simply continue to blow out, as the hole is too small for the material to flow in and fill it up—each coat forming a cap that drops down until the confined air becomes stronger and blows out.

The filler is the foundation of the finish. "As the foundation is, so is the structure," is the old saying. Does it not apply with equal force to a filler finishing? Is it not quite as true that well-filled work requires less varnish to body it up to the requisite volume for a polished surface? Is it not also equally as certain that it requires more scouring to obtain that surface? Now, as a natural sequence to this, would it not be cheaper to pay a little more per piece, have the filling inspected, rejecting it if not up to the standard, get the foundation right, and save both higher-priced material and time?

Thinning.—Quite 90 per cent of the complaints of filler are directly traceable to the thinning. This is in a great measure due to the filler salesman, who represents that 7½ to 8 pounds of filler to the gallon of liquid is all that is necessary to produce good results. An exhaustive investigation of the five most prominent fillers on the market show the best results and least wastage with the following proportions: For ash and mahogany,

$7\frac{1}{2}$; walnut, 8; quartered oak, 12; straight-grained oak, 14; and chestnut, 15 pounds of paste filler to the gallon of liquid.

Another phase of this trouble, and the most serious abuse to which filler is subjected, has grown out of the habit of breaking up the day's supply of filler in the morning. Neglect to stir the filler whilst in use permits the heavier particles to go to the bottom, resulting in using out too large a portion of the binder. When it grows thick turpentine or benzine is added, but no additional binder is supplied, hence the last of the day's work is not so well filled as that of the morning hours, and the varnish coat must supply the deficiency of binder.

STAINS.—Stains are liquid preparations of different tints, applied to the surface of the cheaper woods, in order to give them the appearance of the more rare and expensive woods, such as rosewood, mahogany, walnut, etc.

Suitable stains to imitate different woods may be prepared as follows:

Cherry.—Rain-water, 3 quarts; annetto, 4 ounces; boil in a copper kettle till the annetto is dissolved; then put in a piece of potash the size of a walnut; keep on the fire half an hour and it is then ready for use.

Mahogany.—(1) Put 2 ounces of dragon's blood, bruised, into a quart of oil of turpentine; let stand in a warm place until dissolved, when it is ready for use.

(2) Dragon's blood, $\frac{1}{2}$ ounce; alkanet, $\frac{1}{4}$ ounce; aloes, 1 drachm; spirits of wine, 16 ounces.

Birch.—To finish to represent mahogany, coat with a weak solution of bichromate of potash, then stain with rose-pink Vandyke brown, and burnt Sienna; then shellac, with a little Bismarck brown dissolved in the shellac. This makes a better stain and more lasting than a water stain.

Red.—Brazil-wood, 11 parts; alum, 4 parts; water, 85 parts; boil together.

Blue.—Logwood, 7 parts; blue vitriol, 1 part; water, 22 parts; boil.

Black.—Logwood, 9 parts; sulphate of iron, 1 part; water, 25 parts; boil.

Green.—Verdigris, 1 part; vinegar, 3 parts; dissolve.

Yellow.—French berries, 7 parts; alum, 1 part; water, 10 parts; boil.

Purple.—Logwood, 11 parts; alum, 3 parts; water, 29 parts boil.

Black Walnut.—Burnt umber, 2 parts; rose-pink, 1 part; glue, 1 part; water sufficient to mix; heat and dissovle completely.

Ebony.—Drop-black, 2 parts; rose-pink, 1 part; turpentine sufficient to mix.

Satinwood.—Alcohol, 2 parts; powdered gamboge, 3 ounces; ground turmeric, 6 ounces; steep and strain through muslin.

Rosewood.—Alcohol, 1 gallon; camwood, 2 ounces; set in a warm place twenty-four hours, then add aqua fortis, 1 ounce; extract logwood, 3 ounces; when dissolved is ready for use.

DATA ON PAINTING.—One pound of paint will cover from 3½ to 4 square yards of wood for the first coat, and from 4½ to 6 square yards for each additional coat; on brickwork, it will cover about 3 and 4 square yards respectively. Colored paints will cover about one-fourth more surface than white paint.

Prepared shingle stains will cover about 200 square feet of surface if put on with a brush, or will be sufficient for dipping about 500 smooth shingles or 400 rough ones.

One gallon of liquid filler, hard oil finish, or varnish generally, will cover from 350 to 400 square feet of surface for first coat, and from 400 to 500 square feet of surface for subsequent coats.

One gallon of ready-mixed paint will cover 250 to 300 square feet of wood surface one coat, or 175 to 225 square feet two coats, or 125 to 150 square feet three coats.

White lead and oil will cover about 15 per cent less than the above.

BITUMINOUS, ASPHALT, ETC., PAINTS.—Bituminous or asphalt paints are prepared by dissolving bitumen in paraffine, petroleum, naphtha, or benzine.

P. B. paint is composed of asphaltum, linseed-oil, turpentine, and kauri-gum.

Coal-tar paint is composed of pure coal-tar ,or coal-tar mixed with lime or other inert pigment, and mixed with fish or mineral oils. It is also made by mixing coal-tar and benzine; this makes a fair roof paint. Coal-tar paint is often substituted for asphaltum paint.

Graphite paint is prepared by mixing graphite with boiled linseed-oil to which a small percentage of litharge, red lead, manganese, or other metallic salt has been added at the time of boiling.

Prince's metallic paint is made from a blue magnetic iron ore, containing about 50 per cent of iron peroxide, 25 per cent

limestone, and 25 per cent sulphur. It is mined in Carbon County, Pa. The prepared pigment is said to contain 72 per cent of iron peroxide and 28 per cent of hydraulic cement. It is mixed in oil, and comes in one color, brown. It is one of the best paints for roofs and rough outside work.

There are a number of other metallic paints made from materials similar to Prince's and which possess about the same qualities.

VARIOUS METHODS OF COLORING OAK.—*Flemish Oak.*—Dissolve ½ pound of bichromate of potash in one gallon of water. Coat the wood, and when dry, sandpaper down smooth; then coat with best drop-black, ground japan, thinned with turpentine. Let stand five minutes and wipe off clean; then coat with pure grain shellac and sandpaper with No. 0 sandpaper; then coat with beeswax, 1 pound to a gallon of turpentine, ¼ pound of drop-black mixed in the wax; then wipe off clean with cheese-cloth.

Weathered Oak.—Give the woodwork one coat of strong ammonia. When dry, sandpaper down smooth and stain it with a mixture composed of lampblack, ochre, and 2 pounds of silica to a gallon of stain. Wipe off with cheese-cloth, then give one coat of wax and wipe off clean. If a brownish shade is desired, put in 1 ounce of bichromate of potash and ammonia, or if a greenish shade, put in some green and stain.

Verde Finish.—One ounce of nigrocene dissolved in ½ gallon of water. Give woodwork one coat; when dry sandpaper, care being taken not to rub off the edges; then fill with a bright green filler, with some white lead in the filler. When thoroughly dry, give one coat of pure grain shellac and then wax, or it should be finished with three coats of varnish and rubbed. This finish leaves the pores of a bright-green color, while the rest of the wood is almost black.

Black Oak.—One ounce of nigrocene to ½ gallon of water. Give the woodwork one coat; then fill up with a black filler; then one coat of shellac and three coats of varnish rubbed with pumice-stone and water; then oil and wipe clean.

Birch.—To finish to represent mahogany, coat with a weak solution of bichromate of potash, then shellac, with a little Bismarck brown.

HARMONY AND CONTRAST IN COLORS.—White contrasts with black and harmonizes with gray.

White contrasts with brown and harmonizes with buff.
White contrasts with blue and harmonizes with sky-blue.
White contrasts with purple and harmonizes with rose.
White contrasts with green and harmonizes with pea-green.
Cold greens contrast with crimson and harmonize with olive.
Cold greens contrast with purple and harmonize with citrine.
Cold greens contrast with white and harmonize with blues.
Cold greens contrast with pink and harmonize with brown.
Cold greens contrast with gold and harmonize with black.
Cold greens contrast with orange and harmonize with gray.
Warm greens contrast with crimson and harmonize with yellow.
Warm greens contrast with maroons and harmonize with orange.
Warm greens contrast with purple and harmonize with citrine.
Warm greens contrast with red and harmonize with sky-blue.
Warm greens contrast with pink and harmonize with gray.
Warm greens contrast with white and harmonize with white.
Warm greens contrast with black and harmonize with brown.
Warm greens contrast with lavender and harmonize with buff.
Greens contrast with colors containing red and harmonize with colors containing yellow or blue.
Orange contrasts with purple and harmonizes with yellow.
Orange contrasts with blue and harmonizes with red.
Orange contrasts with black and harmonizes with red.
Orange contrasts with black and harmonizes with warm green.
Orange contrasts with olive and harmonizes with warm brown.
Orange contrasts with crimson and harmonizes with white.
Orange contrasts with gray and harmonizes with buff.
Orange requires blue, black, purple, or dark colors for contrasts and warm colors for harmony.
Citrine contrasts with purple and harmonizes with yellows.
Citrine contrasts with blue and harmonizes with orange.
Citrine contrasts with black and harmonizes with white.
Citrine contrasts with brown and harmonizes with green.
Citrine contrasts with crimson and harmonizes with buff.
Russet contrasts with green and harmonizes with red.
Russet contrasts with black and harmonizes with yellow.
Russet contrasts with olive and harmonizes with orange.
Russet contrasts with gray and harmonizes with brown.
Olive contrasts with orange and harmonizes with green.

Olive contrasts with red and harmonizes with blue.

Olive contrasts with white and harmonizes with black.

Olive contrasts with maroon and harmonizes with brown.

Gold contrasts with any dark color, but looks richer with purple, green, blue, black, and brown than with the other colors. It harmonizes with all light colors, but least with yellow. The best harmony is with white.

Glass.—All glass is composed of three chemical elements, viz., silica, soda, and some metallic oxide. There are three varieties of glass used in architectural work, namely, crown glass, sheet glass, and plate glass.

Crown glass is made by dipping the end of the blow-pipe in the melting-pot and collecting a ball of the molten glass on the end of the tube and blowing the glass into a globe. This globe is again heated while it is rotated rapidly and spreads out into a large flat, called a "table," under the influence of the centrifugal force of rotation. This flat piece of glass is then cut up into panes.

Sheet glass is made similarly to crown glass except that the glass as it is blown is rolled on a moulding block, causing the glass to take the form of a long cylinder. The ends of this cylinder are cut off and the cylinder split lengthwise; the split cylinder is then put in the flattening-kiln, where it is heated and flattened out into a flat sheet of glass. When cooled it is cut into panes.

Plate glass is pressed or rolled on a table by a large iron roller, the glass is squeezed out before the advancing roller and pressed into a sheet of the desired size. The thickness of the sheet is gauged by strips of metal on each side of the table. The sheets after being rolled are put into the annealing-oven for several days and then polished by grinding to an even surface and polishing and smoothing with fine emery and felt rubbers.

The defects in glass are very apparent and consist of waves, air-bubbles, twists, sand-specks, and patches of color.

Sheet glass is of various qualities, weighing from 12 to 42 ounces per square foot. Every $\frac{1}{16}$ inch in thickness adds about 13 ounces to the weight per square foot. Glass is usually sold by the box, containing 50 square feet of glass regardless of the size of the panes; it is sold in three thicknesses and grades, viz., AA, A, and B, of which AA is the best and thickest. On the Pacific Coast it is usually graded by weight as 15-ounce,

21-ounce, and 26-ounce glass, and which corresponds to the AA, A, and B grades of the Eastern market.

The thickness of the ordinary window glass is known as single strength and double strength. Thus AA double strength would mean the best quality and thickness.

The finished plates of polished plate glass varies in thickness from $\frac{1}{4}$ to $\frac{3}{8}$ inch.

GLAZING.—All glass should be bedded in a layer of putty spread in the rebate of the sash and the glass pressed down

ROLLS OF PAPER REQUIRED TO COVER THE WALLS OF A ROOM.

Size of Room.	Height of Ceiling.	Number of Doors.	Number of Windows.	Rolls of Paper.	Yards of Border.
7× 9.......	8	1	1	6	11
7× 9.......	9	1	1	7	11
7× 9.......	10	1	1	8	11
7× 9.......	12	1	1	10	11
8×10.......	8	1	1	7	12
8×10.......	9	1	1	8	12
8×10.......	10	1	1	9	12
8×10.......	12	1	1	11	12
9×11.......	8	1	1	8	14
9×11.......	9	1	1	10	14
9×11.......	10	1	1	11	14
9×11.......	12	1	1	13	14
10×12.......	8	1	1	9	14
10×12.......	9	1	1	10	15
10×12.......	10	1	1	11	15
10×12.......	12	1	1	13	15
11×12.......	8	2	2	8	16
11×12.......	9	2	2	9	16
11×12.......	10	2	2	10	16
11×12.......	12	2	2	13	16
12×13.......	8	2	2	8	17
12×13.......	9	2	2	10	17
12×13......	10	2	2	11	17
12×13.......	12	2	2	14	17
12×15.......	8	2	2	10	18
12×15.......	9	2	2	11	18
12×15.......	10	2	2	12	18
12×15......	12	2	2	15	18
13×15.......	8	2	2	10	19
13×15.......	9	2	2	11	19
13×15.......	10	2	2	13	19
13×15.......	12	2	2	16	19
14×16.......	9	2	2	12	20
14×16.......	10	2	2	14	20
14×16.......	12	2	2	17	20
14×18.......	9	2	2	13	22
14×18.......	10	2	2	15	22
14×18.......	12	2	2	19	22
15×16.......	10	2	2	15	21
15×17.......	12	2	2	19	22

Deduct one-half roll of paper for each ordinary door or window extra—size, 4×7 feet.

A double roll of wall-paper contains about 72 square feet.

into this bed so as to lay solid; it should then be secured with a sufficient number of points or "sprigs" and then "front glazed." In glazing the sash care must be taken not to put the putty on heavy enough to project over the wood rebate and thus show from the inside of the sash. All sash should have a coat of paint or oil before being glazed, so the putty will take hold of the wood.

PAPER-HANGING.—To prepare the walls, make a size of glue and water, then give the walls a coat of a very weak solution of the same. To make a paste, take 2 pounds of fine flour, put in a pail, add cold water, and stir it up together in a thick paste. Take a piece of alum about the size of a small chestnut, pound it fine and throw it into the paste; mix well. Then take about 6 quarts of boiling water and mix with the paste while hot until the whole is brought to a proper consistency. This makes an excellent paste, and is fit for use when cold.

The table on page 421 shows how many single rolls of wall-paper are required to cover the walls of a room of the dimensions indicated by the figures in the left-hand column, also the number of yards of border required.

Cast Iron.—Cast iron is the remelted pig iron run in moulds of the desired shape. A cast-iron casting should show a smooth clean surface and have all angles run true and sharp. There should be no "blow" or "sand" holes.

Cast iron when broken should show a close-grained texture, and the fracture should have a light-bluish color. The iron should be soft enough so it can be dented by a blow of a hammer on a corner without breaking off pieces.

The superintendent should examine all cast iron closely, as very often "blow" or "sand" holes are stopped up with putty.

A casting when struck with a hammer should give a clear ring; if it gives a dull sound it indicates a crack or holes stopped up.

Cast-iron columns should be examined as to the thickness of the metal, for if the core in casting has been placed a little out of centre then the column will have thick iron on one side and thin iron on the other.

Cast-iron pipes should be tapped with a hammer to sound for cracks, "blow" or "sand" holes, and also examined to see if they are of the required thickness, and that the bead and hub are well formed.

SPECIFICATIONS FOR STRUCTURAL CAST IRON.

STRUCTURAL CAST IRON.—Except when chilled iron is specified, all castings shall be tough gray iron, free from injurious cold-shuts or blow-holes, true to pattern, and of a workmanlike finish. Sample pieces 1 inch square, cast from the same heat of metal in sand moulds, shall be capable of sustaining on a clear span of 4 feet 8 inches a central load of 500 pounds when tested in the rough bar.

DATA REGARDING CAST IRON.—Specific gravity, 7.10 to 7.50.

Weight per cubic foot, 450 pounds.

Ultimate strength: Tensile, 13,000 to 29,000 pounds per square inch; compressive, 85,000 to 125,000 pounds per square inch; shearing, 25,000 pounds per square inch; torsion, 8600 pounds per square inch; transverse, 500 to 4000 pounds per square inch.

Working strength: Tensile, 3000 pounds per square inch; compressive, 80,000 pounds per square inch; transverse, 600 pounds per square inch; shearing, 6000 pounds per square inch; torsion, 5000 pounds per square inch.

Shrinkage, $\frac{1}{8}$ inch per foot.

Melting-point, 2000° F.

MALLEABLE CAST IRON.—Malleable cast iron is cast iron which has been deprived of some of its carbon by heating to a red heat, together with some chemical compound having a strong affinity for carbon, and then allowing it to cool slowly. Such castings are not as brittle as the ordinary cast iron.

STRENGTH OF MALLEABLE CAST IRON.

Tensile.	25,000 to 50,000 pounds per square inch.
Elongation.	1 to 2 per cent in 4 inches.
Elastic limit.	15,000 to 21,000.

The same care should be taken in examining malleable cast-iron castings as with the ordinary cast iron.

The use of cast or malleable iron for structural purposes should be confined to those parts or members which only will have to withstand a compressive strain.

The following tables, on pages 424 and 425, gives the strength and safe load for cast-iron columns.

ULTIMATE STRENGTH OF HOLLOW ROUND AND HOLLOW RECTANGULAR CAST-IRON COLUMNS.

Ultimate strength in pounds per square inch:

Round Columns.			Rectangular Columns.		
Square Bearing.	Pin and Square.	Pin Bearing.	Square Bearing.	Pin and Square.	Pin Bearing.
$\dfrac{80000}{1+\dfrac{(12l)^2}{800d^2}}$	$\dfrac{80000}{1+\dfrac{3(12l)^2}{1600d^2}}$	$\dfrac{80000}{1+\dfrac{(12l)^2}{400d^2}}$	$\dfrac{80000}{1+\dfrac{3(12l)^2}{3200d^2}}$	$\dfrac{80000}{1+\dfrac{9(12l)^2}{6400d^2}}$	$\dfrac{80000}{1+\dfrac{3(12l)^2}{1600d^2}}$

l = length of column in feet;
d = external diameter or least side of rectangle in inches.

$\frac{l}{d}$	Round Columns. Ultimate Strength in Pounds per Square Inch.			Rectangular Columns. Ultimate Strength in Pounds per Square Inch.		
	Square Bearing.	Pin and Square.	Pin Bearing.	Square Bearing.	Pin and Square.	Pin Bearing.
1.0	67800	62990	58820	70480	66520	62990
1.1	65690	60300	55730	68790	64260	60300
1.2	63530	57600	52690	67000	61940	57600
1.3	61340	54930	49740	65140	59600	54960
1.4	59140	52310	46900	63260	57270	52320
1.5	56940	49770	44200	61350	54960	49760
1.6	54760	47300	41630	59450	52680	47300
1.7	52620	44940	39210	57550	50460	44960
1.8	50530	42670	36930	55670	48300	42670
1.9	48490	40510	34790	53800	46230	40510
2.0	46510	38460	32790	51940	44200	38460
2.1	44600	36520	30920	50160	42260	36520
2.2	42750	34680	29180	48400	40400	34680
2.3	40980	32940	27540	46670	38630	32950
2.4	39280	31310	26030	44990	36930	31310
2.5	37650	29770	24620	43390	35310	29760
2.6	36090	28320	23300	41820	33770	28320
2.7	34600	26950	22070	40320	32310	26950
2.8	33180	25670	20930	38870	30920	25670
2.9	31820	24460	19860	37470	29600	24460
3.0	30530	23320	18870	36120	28340	23320
3.1	29310	22250	17940	34830	27150	22250
3.2	28140	21250	17070	33580	26030	21250
3.3	27030	20300	16260	32390	24960	20300
3.4	25970	19410	15500	31240	23940	19410

SAFE LOADS IN TONS OF 2000 LBS. FOR HOLLOW ROUND CAST-IRON COLUMNS.

Outside Diameter, Inches.	Thickness of Metal.	Length of Columns in Feet.									Sectional Area, Inches.	Weight, Lbs. of Col. per Ft. of L'gth.
		8	10	12	14	16	18	20	22	24		
		Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons	Tons		
6	½	26.2	23.0	20.1	17.5	15.2	13.2	11.5	.....	.....	8.6	26.95
6	¾	37.5	33.0	28.8	25.0	21.7	18.9	16.5	.....	.....	12.4	38.59
6	⅞	42.7	37.6	32.8	28.5	24.7	21.5	18.8	.....	.....	14.1	43.96
6	1	47.6	41.9	36.5	31.8	27.6	24.0	21.0	.....	.....	15.7	49.01
6	1⅛	52.2	46.0	40.1	34.8	30.2	26.3	23.0	.....	.....	17.2	53.76
7	¾	47.7	43.1	38.5	34.3	30.4	26.9	23.9	21.2	18.9	14.7	45.96
7	1	61.1	55.2	49.3	43.8	38.9	34.4	30.6	27.1	24.2	18.9	58.90
7	1⅛	67.2	60.8	54.3	48.3	42.8	37.9	33.7	29.9	26.7	20.8	64.77
8	¾	57.9	53.3	48.6	44.1	39.7	35.8	32.2	28.9	26.1	17.1	53.29
8	1	74.6	68.7	62.5	56.7	51.1	46.0	41.4	37.3	33.6	22.0	68.64
8	1¼	89.9	82.8	75.5	68.4	61.7	55.5	49.9	44.9	40.5	26.5	82.71
9	¾	68.1	63.6	58.9	54.2	49.6	45.2	41.2	37.5	34.1	19.4	60.65
9	1	88.0	82.3	76.2	70.0	64.1	58.4	53.2	48.4	44.1	25.1	78.40
9	1¼	106.6	99.6	92.2	84.8	77.6	70.8	64.4	58.7	53.4	30.4	94.94
9	1½	123.8	115.7	107.1	98.5	90.1	82.2	74.8	68.1	62.0	35.3	110.26
9	1¾	139.6	130.5	120.8	111.1	101.6	92.7	84.4	76.8	69.9	39.9	124.36
10	1	101.4	95.9	89.8	83.6	77.4	71.5	65.8	60.5	55.5	28.3	88.23
10	1¼	123.3	116.5	109.1	101.6	94.1	86.8	79.9	73.4	67.5	34.4	107.23
10	1½	143.7	135.8	127.3	118.5	109.7	101.2	93.2	85.6	78.7	40.1	124.99
10	1¾	162.7	153.8	144.1	134.1	124.2	114.6	105.5	97.0	89.1	45.4	141.65
11	1	114.8	109.4	103.5	97.3	91.0	84.8	80.2	73.1	67.7	31.4	98.03
11	1¼	139.9	133.3	126.1	118.6	110.9	103.3	97.8	89.4	82.5	38.3	119.46
11	1½	163.5	155.9	147.5	138.6	128.7	120.8	114.3	104.1	96.4	44.8	139.68
11	1¾	185.7	177.1	167.5	157.5	147.3	137.2	129.8	118.3	109.5	50.9	158.68
11	2	206.6	196.9	186.3	175.1	163.8	152.6	144.4	131.5	121.8	56.6	176.44
12	1	128.0	122.9	117.2	111.0	104.7	98.4	92.2	86.1	80.4	34.6	107.51
12	1¼	156.4	150.1	143.1	135.7	127.9	120.2	112.6	105.2	98.2	42.2	131.41
12	1½	183.3	175.9	167.7	159.0	149.9	140.9	132.0	123.3	115.1	49.5	154.10
12	1¾	208.7	200.4	191.0	181.1	170.7	160.4	150.3	140.5	131.1	56.4	175.53
12	2	232.7	223.4	213.0	201.9	190.4	178.9	167.6	156.6	146.1	62.8	195.75
13	1	141.2	136.3	130.7	124.7	118.5	112.1	105.8	99.5	93.5	37.7	117.53
13	1¼	172.8	166.8	160.0	152.7	145.0	137.2	129.4	121.8	114.4	46.1	143.86
13	1½	203.0	195.9	187.9	179.3	170.3	161.1	152.0	143.1	134.3	54.2	168.98
13	1¾	231.6	223.6	214.5	204.7	194.4	183.9	173.5	163.3	153.3	61.9	192.88
13	2	258.9	249.9	239.7	228.7	217.3	205.5	193.9	182.5	171.3	69.1	215.56
14	1	154.3	149.6	144.3	138.5	132.3	125.9	119.5	113.1	106.8	40.8	127.60
14	1¼	189.2	183.4	176.9	169.7	162.2	154.4	146.5	138.6	131.0	50.1	156.31
14	1½	222.6	215.8	208.1	199.7	190.8	181.7	172.3	163.1	154.1	58.9	183.67
14	1¾	254.4	246.7	237.9	228.3	218.1	207.6	197.0	186.5	176.2	67.4	210.00
14	2	284.8	276.2	266.4	255.6	244.2	232.4	220.6	208.8	197.2	75.4	235.12
15	1	167.4	162.9	157.8	152.1	146.0	139.7	133.3	126.8	120.4	44.0	137.28
15	1¼	205.5	200.0	193.7	186.7	179.3	171.5	163.6	155.7	147.9	54.0	168.48
15	1½	242.1	235.7	228.2	220.0	211.2	202.1	192.8	183.5	174.2	63.6	198.74
15	1¾	277.2	269.8	261.3	251.9	241.9	231.4	220.7	210.1	199.5	72.9	227.45
15	2	310.8	302.5	293.0	282.5	271.2	259.5	247.5	235.5	223.6	81.7	254.90

If all cast-iron or other hollow columns are filled with concrete after being set it adds to their strength and affords protection from rust and fire.

Wrought Iron.—Wrought iron, when perfect, is simply pure iron; wrought iron has the advantage over other iron in that it can be welded when heated to nearly a white heat.

Good iron should be soft and tough, and when broken should show small crystals of a uniform size and color, and fine silky fibres, or if broken gradually should show long silky fibres of a gray-bluish color.

Good iron should bend cold 180° degrees around a circle whose diameter is twice the thickness of the piece, for bar iron, and three times the thickness for plates.

Data on Wrought Iron.

Specific gravity 7.79.

Weight per cubic foot 480 to 485 pounds per cubic foot.

Melting-point 2734° to 3000° Fahr.

Ultimate tensile strength 30,000 to 70,000 pounds.

Ultimate compressive strength 40,000 to 125,000 pounds.

Ultimate shearing strength 40,000 pounds.

Working strength, tensile, 10,000 to 15,000 pounds per square inch.

Working strength, compressive, 36,000 pounds per square inch.

Working strength, shearing, 6000 to 9000 pounds per square inch.

Structural Iron and Steel.—Steel is a compound of iron with from .01 to 1.5 per cent of carbon. It also contains minute quantities of silicon, sulphur, phosphorus, etc. The process of making steel may be classed under two heads: by adding carbon to wrought iron, and by abstracting carbon from cast iron. The former is used for making tool steel and the latter for making large masses of steel for ordinary uses.

Good soft steel should bend cold through 180°, and close down flat upon itself without cracking.

A simple test for iron or steel is to take a small sample, file it smooth on all sides, and place it in dilute nitric or sulphuric acid for about twelve hours, then wash and dry it. The action of the acid will show the structure of the material, from which its quality can be judged.

The best steel will show a frosty appearance; ordinary steel, honeycombed; the best iron will show fine fibres, while if the composition or structure of the iron is uneven, the acid will reveal it.

All structural steel or iron work should be inspected at the shops, just before being riveted together, and again after the work is finished and ready for painting.

When inspecting the work at the shop notice should be taken to see that all members, beams, etc., are perfectly straight, and that all are of the dimensions called for by the drawings. The superintendent, or inspector, should examine each piece as to dimensions, locations of rivets, bolt-holes, etc., and see that they are all located correctly. He should see that the holes for riveting are of the correct size and that when the work is put together the holes come directly opposite each other. As each piece is inspected it should be stamped or marked so that when it is received at the work there will be an indication of shop inspection.

As the material is delivered at the work, the superintendent should examine it for the shop inspector's mark, and if there is any which does not bear this mark, when there has been a shop inspection made, it should be examined closely for defects.

The superintendent should see that the work has been properly painted, and if not, have a coat of paint put on as soon as possible. He should also see that all columns or other members have been faced off as required by the specifications.

In erecting the work all columns, etc., should be started level, so they will be carried level throughout the structure.

As the work is put together, he should see that all holes for bolts or rivets come opposite, and should not allow the drift-pin to be used except for drawing the work together. If the bolt or rivet will not enter he should have the hole reamed out and a larger bolt or rivet used.

Where bolts are used in any of the flanges of the members bevelled washers should be used on the bevelled flange.

As soon as the work is put together he should see that it receives a coat of paint at once, and have any rust which may appear scraped off.

The following, by C. J. Tilden, Assoc. M. Am. Soc. C. E., Assistant Engineer New York Rapid Transit Commission, 242 St. Nicholas Ave., New York City, is very instructive in regard to riveting, etc.

RIVETS IN STRUCTURAL STEEL WORK.* — A theoretically perfect rivet should fill the hole completely, be of homogeneous material throughout, and have two well-formed heads. The

* Condensed from an article in the *Harvard Engineering Journal.*

strength of a riveted joint depends, theoretically, on but two considerations: first, the shearing strength of the rivet material, usually soft steel; and, second, the number of rivets used. When comparatively thin plates are joined by rivets of large diameter, it may happen that the resistance of the metal to crushing is less than the shearing strength of one rivet; in which case the crushing or "bearing" value of the metal determines the value to be given to each rivet in calculating the strength of the joint. The question then arises with what degree of safety may the designing engineer accept these theoretical assumptions, and how are they borne out by the conditions which occur in shop practice?

In the first place, the material of a rivet is not homogeneous In a large majority of cases it is probable that test-pieces taken from different parts of a rivet after driving, assuming that such small pieces could be properly tested, would show widely different characteristics, and these totally different from similar tests of the same rivet before driving. A very good idea of the great difference in quality of rivet material after driving may be gained by watching for a few hours a shop-gang engaged in cutting out rivets which have been condemned by the inspector. Sometimes the metal is hard, tough, and fibrous; then again nearly as soft, to all appearances, as lead or pewter; and occasionally the rivet-head will fly off at the first blow of the hammer, apparently almost as hard and brittle as glass.

A second noteworthy discrepancy in the design of riveted joints is the failure to take account of the action of the rivet-heads in bringing the two or more surfaces into very close contact, so that a large amount of friction is developed. It is quite possible that this friction may amount to more than the shearing strength of the rivet. In any event it is a very important factor in the strength of a riveted joint.

In the diagram, Fig. 240, are shown some of the more frequent imperfections in rivet-work, resulting from carelessness of the workmen. At *a*, for comparison, is sketched a perfectly driven rivet. The original form is shown dotted, the "shank" being $\frac{1}{16}$ or $\frac{3}{32}$ of an inch less in diameter than the hole which it is to fill, and enough longer than the "grip" or length between heads, to allow the formation of the new head, and the squeezing out of the rivet material sufficiently to fill the hole completely. Both heads should be concentric with the shank, and the rivet

should be perfecly tight, giving a clear, sharp ring when struck with a light hammer.

At *b* is shown a loose rivet which has been "calked," with a cold-chisel, to make it appear tight under the inspector's hammer —a favorite trick of careless riveting-gangs, and often very difficult to detect; if suspected, a close examination should be made of the head of the rivet for signs of the calking-tool, especially if the rivet has been generously bespattered with fresh paint or tobacco-juice. Both these commodities, always plentiful in the shop, are favorite means of concealment for "scamped" work of this character. A result very similar to calking, but much harder to discover, is sometimes secured by using the riveting-machine, or "bull" as it is familiarly known to the shop men, on the cold rivet. The movable cup of the 'bull" is brought sharply against the rivet-head, securing somewhat the effect of a blow, and this is repeated four or five times on each loose rivet. In general, this machine-calking is not very effective, but the writer has known instances where it has been successful. It is well-nigh impossible to tell from the appearance of the rivet-head afterwards if this trick has been attempted. A very slight polish on the head of the rivet is about all the evidence that ever appears, and this is readily hidden by a dab of grease or dirt, or the ever-ready tobacco-juice. It is a form of "scamping" that is seldom resorted to, however, as it is more

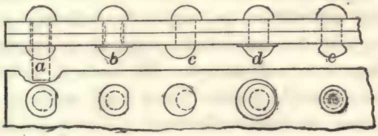


Fig. 240.

Fig. 241.

work than calking with the cold-chisel, and far less likely to accomplish its purpose.

The sketch, *b*, also shows the probable result of heating the rivet unevenly. Where the heating is done in an ordinary portable forge, fired with coke, the forge-tender gets into the habit of heating only that part of the rivet which is to be upset to form the head, leaving the remainder comparatively cool. Referring to Fig. 241, for example, from the lower end of the rivet to, perhaps, the point x, the metal is at white heat; above that it cools rapidly until the head is practically "cold," often

not even a dull-red color. This uneven heating not only prevents the rivet from upsetting throughout its length, and so filling the hole, but is apt to injure the quality of the metal above the point *x*, owing to its being worked under the hammer at too low a temperature.

Careless manipulation of the riveting-machine may result in the condition shown at *c*, where the head is not concentric with the shank. The fault can be detected only by comparison with the other rivets in the joint, showing uneven spacing and irregular lines.

The condition shown at *d* results from too much metal in the shank of the rivet before driving, giving a "soldier-cap" head. The reverse of this is shown at *e*.

It must not be supposed that these defects are the only ones which occur in rivet-work; they are only a few of the more frequent errors of this kind that may be observed in any shop. Combinations of two or more of the forms shown occur not infrequently, and an almost endless variety of changes may be rung on each one. Of the four types, *b* and *e* should be condemned unquestionably whenever found, being not only bad workmanship, but unreliable; *c* and *d* probably develop the full strength of the rivet, and may be allowed to pass if strength is the only consideration; but if the work is to be exposed they should be cut out and replaced, as they are sure to look ragged in finished work.

As to the actual difference in strength between a perfect rivet, as *a*, and any of the imperfect ones, it is impossible to judge with any degree of accuracy. In fact, if a test were made it is quite conceivable that a rivet such as *b*, or even *e*, might develop greater strength than *a*. About all that can be said is that this is not likely to happen, but rather the reverse, as a properly driven rivet is more likely to develop its full strength than one which is imperfect in any way. But this is not reducing the question to any scientific basis, and, indeed, it cannot be so reduced. Rigid specifications are required for riveted work, and the work in the shop is subjected to the most careful inspection, not because a carelessly driven rivet is less strong, by any definitely calculable percentage, than one which is properly driven, but for the simple reason that careful and accurate work is more reliable.

The nearest approach to a theoretically perfect rivet is probably the turned bolt which is occasionally used for field con-

nections. In such cases it is the practice of some engineers to require the holes to be drilled instead of punched, or "sub-punched and reamed"—that is, punched to a diameter about $\frac{1}{4}$ inch less than that of the bolt to be used and reamed to proper size. The bolt is turned to a driving fit, and the threaded part is of slightly reduced diameter, the shoulder, *s*, protecting the thread while the bolt is driven home. To keep the nut in place after it is screwed up tight, the projecting threaded end of the bolt is upset against the nut. In spite of the reliability of this connection, however, its high cost precludes its general use.

Fig. 241 shows a form of rivet which has certain advantages and disadvantages over the ordinary shape. In this form the shank is slightly increased in diameter (exaggerated in the drawing) for a distance of $\frac{1}{2}$ to $\frac{3}{4}$ inch from the head. Directly under the head, at the base of the cone-like enlargement, the shank has the same diameter as the hole into which the rivet is to go—that is, from $\frac{1}{16}$ to $\frac{3}{32}$ inch larger than the main part of the shank. This is an advantage in the shop, where the rivet is sure to be uniformly heated throughout its length, as it insures the complete filling of the hole up to the rivet-head. In the field, however, where the rivets are likely to be unevenly heated, such a design would be of doubtful advantage. A rivet of this shape might easily appear sound and tight under the inspector's hammer, and yet have been very imperfectly driven.

TABLES ON RIVETS.—On pages 432 and 433 are given tables on the shearing and bearing value of rivets.

EXPLANATION OF TABLES.—Intransmitting stresses by means of rivets, it is customary to disregard the friction between the parts joined as too uncertain an element to be relied upon to any extent. The rivets must then be proportioned for the entire stress which is to be transmitted from one plate or group of plates to the other, and they must be of sufficient size and number to present ample resistance to shearing and afford sufficient bearing area so as not to cause a crushing of the metal at the rivet-holes. This latter condition, while generally observed for pins, is very often entirely overlooked in riveted work. Its observance, in most cases of riveted girders with single webs, determines the size and number of rivets to be used and frequently makes it necessary to adopt a greater thickness of web than would otherwise be required. Thus, if the web is $\frac{5}{16}$ inch thick, the rivets connecting the same with

SHEARING AND BEARING VALUE OF RIVETS.

(All Dimensions in Inches.)

Diameter of Rivet. Inches. Fraction.	Decimal.	Area in Square Inches.	Single Shear at 6000 Lbs.	Bearing Value for $\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$
$\frac{3}{8}$	.375	.1104	660	1130	1410	1690	....
$\frac{1}{2}$	.500	.1963	1180	1500	1880	2250	2630
$\frac{5}{8}$	.625	.3063	1840	1880	2340	2810	3280
$\frac{3}{4}$	.750	.4418	2650	2250	2810	3380	3940
$\frac{7}{8}$	.875	.6013	3610	2630	3280	3940	4590
1	1.000	.7854	4710	3000	3750	4500	5250

Diameter of Rivet. Inches. Fraction.	Decimal.	Area in Square Inches.	Single Shear at 7500 Lbs.	Bearing Value for $\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$
$\frac{3}{8}$	.375	.1104	830	1410	1760	2110	....
$\frac{1}{2}$	.500	.1963	1470	1880	2340	2810	3280
$\frac{5}{8}$	.625	.3068	2300	2340	2930	3520	4100
$\frac{3}{4}$	.750	.4418	3310	2810	3520	4220	4920
$\frac{7}{8}$	.875	.6013	4510	3280	4100	4920	5740
1	1.000	.7854	5890	3750	4690	5620	6560

Diameter of Rivet. Inches. Fraction.	Decimal.	Area in Square Inches.	Single Shear at 10000 Lbs.	Bearing Value for $\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$
$\frac{3}{8}$	.375	.1104	1100	1880	2340	2810	....
$\frac{1}{2}$	.500	.1963	1960	2500	3130	3750	4380
$\frac{5}{8}$	.625	.3068	3070	3130	3910	4690	5470
$\frac{3}{4}$	.750	.4418	4420	3750	4690	5630	6560
$\frac{7}{8}$	.875	.6013	6010	4380	5470	6570	7660
1	1.000	.7854	7850	5000	6250	7500	8750

Diameter of Rivet. Inches. Fraction.	Decimal.	Area in Square Inches.	Single Shear at 12000 Lbs.	Bearing Value for $\frac{1}{4}$	$\frac{5}{16}$	$\frac{3}{8}$	$\frac{7}{16}$
$\frac{3}{8}$	.375	.1104	1320	2350	2930	3520	....
$\frac{1}{2}$	.500	.1963	2360	3130	3910	4690	5470
$\frac{5}{8}$	.625	.3063	3680	3910	4880	5860	6840
$\frac{3}{4}$	.750	.4418	5300	4690	5860	7030	8210
$\frac{7}{8}$	.875	.6013	7220	5470	6840	8210	9580
1	1.000	.7854	9430	6250	7820	9380	10940

In above tables all bearing values above or to right of upper zigzag lines are greater than double shear. Values between upper and lower zigzag lines are less than double and greater than single shear.

SHEARING AND BEARING VALUE OF RIVETS.

(All Dimensions in Inches.)

Different Thicknesses of Plate in Inches at 12,000 Lbs. per Square Inch.

$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
....	....	....	....	....	....	....	....	....
3000	....	....	....	....	....	....	....	....
3750	4220	4690	....	....	....	....	....	....
4500	5060	5630	6190	6750	....	....	....	....
5250	5910	6560	7220	7880	8530	9190	9840	....
6000	6750	7500	8250	9000	9750	10500	11250	12000

Different Thicknesses of Plate in Inches at 15,000 Lbs. per Square Inch.

$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
....	....	....	....	....	....	....	....	....
3750	....	....	....	....	....	....	....	....
4690	5280	5860	....	....	....	....	....	....
5630	6330	7030	7720	8440	....	....	....	....
6560	7380	8200	9030	9850	10670	11480	12300	....
7500	8440	9380	10310	11250	12190	13130	14060	15000

Different Thicknesses of Plate in Inches at 20,000 Lbs. ber Square Inch.

$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
....	....	....	....	....	....	....	....	....
5000	....	....	....	....	....	....	....	....
6250	7030	7810	....	....	....	....	....	....
7500	8440	9380	10310	11250	....	....	....	....
8750	9840	10940	12030	13130	14220	15310	16410	....
10000	11250	12500	13750	15000	16250	17500	18750	20000

Different Thicknesses of Plate in Inches at 25,000 Lbs. per Square Inch.

$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$	$\frac{13}{16}$	$\frac{7}{8}$	$\frac{15}{16}$	1
....	....	....	....	....	....	....	....	....
6250	....	....	....	....	....	....	....	....
7810	8790	9770	....	....	....	....	....	....
9380	10550	11720	12890	14060	....	....	....	....
10940	12310	13670	15040	16410	17770	19140	20510	....
12500	14060	15630	17190	18750	20320	21880	23440	25000

Values below and to left of lower zigzag lines are less than single shear.

the flange angles have a bearing value of only 3520 pounds for a $\frac{3}{4}$-inch rivet, while their shearing value is $=2\times3310=6620$ pounds per rivet, the rivets being in double shear. Consequently, while the usual thickness of web of floor-beams for railway bridges is $\frac{3}{8}$ inch, it sometimes becomes necessary for shallow floor-beams to increase this thickness to $\frac{1}{2}$ inch and even $\frac{5}{8}$ inch, in order that the pressure of the rivets upon the semi-intrados of the rivet-holes be not excessive between the points of support of floor-beam and of application of the load

FIG. 242.

(in which space the transmission of strain from web to flanges takes place).

Fig. 242 shows the signs used by draughtsmen to designate the shape and style of rivets desired in the work.

The following requirements for iron and steel construction is taken from the New York Building Code.

Sec. 21. STRUCTURAL MATERIAL.—*Wrought Iron.*—All wrought iron shall be uniform in character, fibrous, tough, and ductile. It shall have an ultimate tensile resistance of not less than 48,000 lbs. per square inch, an elastic limit of not less than 24,000 lbs. per square inch, and an elongation of 20 per cent in eight inches, when tested in small specimens.

Steel.—All structural steel shall have an ultimate tensile strength of from 54,000 pounds to 64,000 pounds per square inch. Its elastic limit shall be not less than 32,000 pounds per square inch and a minimum elongation of not less than 20 per cent in eight inches. Rivet steel shall have an ultimate strength of from 50,000 to 58,000 pounds per square inch.

Cast Steel.—Shall be made of open-hearth steel, containing one-quarter to one-half per cent of carbon, not over eight one-hundredths of one per cent of phosphorus, and shall be practically free from blow-holes.

Cast Iron.—Shall be of good foundry mixture, producing a clean, tough, gray iron. Sample bars, five feet long, one inch square, cast in sand moulds, placed on supports four feet six inches apart, shall bear a central load of 450 pounds before breaking. Castings shall be free of serious blow-holes, cinder-spots, and cold-shuts. Ultimate tensile strength shall be not less than 16,000 pounds per square inch when tested in small specimens.

SPECIFICATIONS FOR IRON AND STEEL CONSTRUCTION.

Sec. 110. *Skeleton Construction.*—Where columns are used to support iron or steel girders carrying inclosure walls, the said columns shall be of cast iron, wrought iron, or rolled steel, and on their exposed outer and inner surfaces be constructed to resist fire by having a casing of brickwork not less than eight inches in thickness on the outer surfaces, nor less than four inches in thickness on the inner surfaces, and all bonded into the brickwork of the inclosure walls. The exposed sides of the iron or steel girders shall be similarly covered in with brickwork not less than four inches in thickness on the outer surfaces and tied and bonded, but the extreme outer edge of the flanges of beams, or plates or angles connected to the beams, may project to within two inches of the outside surface of the brick casing. The inside surfaces of girders may be similarly covered with brickwork, or if projecting inside of the wall, they shall be protected by terra-cotta, concrete, or other fire-proof material. Girders for the support of the inclosure walls shal be placed at the floor line of each story.

Sec. 111. *Steel and Wrought-iron Columns.*—No part of a steel or wrought-iron column shall be less than one-quarter of an inch thick. No wrought-iron or rolled-steel column shall have an unsupported length of more than forty times its least lateral dimension or diameter, except as modified by Section 138 of this Code, and also except in such cases as the commissioners of buildings may specially allow a greater unsupported length.

The ends of all columns shall be faced to a plane surface at right angles to the axis of the columns and the connection between them shall be made with splice-plates. The joint may be effected by rivets of sufficient size and number to transmit the entire stress, and then the splice-plates shall be equal in sectional area to the area of columns spliced. When the section of the columns to be spliced is such that splice-plates cannot be used, a connection formed of plates and angles may be used, designed to properly distribute the stress. No material, whether in the body of the column or used as lattice-bar or stay-plate, shall be used in any wrought-iron or steel column of less thickness than one-thirty-second of its unsupported width measured between centres of rivets transversely, or one-sixteenth the distance between centres of rivets in the direction of the stress. Stay-plates are to have not less than four rivets, and are to be spaced so that the ratio of length by the least radius of gyration of the parts connected does not exceed forty; the distance between nearest rivets of two stay-plates shall in this case be considered as length. Steel and wrought-iron columns shall be made in one, two, or three-story lengths, and the materials shall be rolled in one length wherever practicable to avoid intermediate splices. Where any part of the section of a column projects beyond that of the column below, the difference shall be made up by filling plates secured to column by the proper number of rivets. Shoes of iron or steel, as described for cast-iron columns, or built shoes of plates and shapes may be used, complying with same requirements.

Sec. 112. *Cast-iron Columns.*—Cast-iron columns shall not have less diameter than five inches or less thickness than three-quarters of an inch; nor shall they have an unsupported length of more than twenty times their least lateral dimensions or diameter, except as modified by Section 138 of this Code, and except the same may form part of an elevator inclosure or staircase, and also except in such cases as the commissioner of buildings having jurisdiction may specially allow a greater unsupported length. All cast-iron columns shall be of good workmanship and material. The top and bottom flanges, seats, and lugs shall be of ample strength, reinforced by fillets and brackets; they shall be not less than one inch in thickness when finished. All columns must be faced at the ends to a true surface perpendicular to the axis of the column. Column joints shall be secured by not less than four bolts each, not less

than three-quarters of an inch in diameter. The holes for these bolts shall be drilled in a template. The core of a column below a joint shall be not larger than the core of the column above and the metal shall be tapered down for a distance of not less than six inches, or a joint plate may be inserted of sufficient strength to distribute the load. The thickness of metal shall be not less than one-twelfth the diameter or the greatest lateral dimension of cross-section, but never less than three-quarters of an inch. Wherever the core of a cast-iron column has shifted more than one-fourth the thickness of the shell, the strength shall be computed assuming the thickness of metal all around equal to the thinnest part, and the column shall be condemned if this computation shows the strength to be less than required by this Code. Wherever blow-holes or imperfections are found in a cast-iron column which reduces the area of the cross-section at that point more than ten per cent, such column shall be condemned. Cast-iron posts or columns not cast with one open side or back, before being set up in place, shall have a three-eighths of an inch hole drilled in the shaft of each post or column, by the manufacturer or contractor furnishing the same, to exhibit the thickness of the castings; and any other similar sized hole or holes which the commissioners of buildings may require shall be drilled in the said posts or columns by the said manufacturer or contractor at his own expense.

Iron or steel shoes or plates shall be used under the bottom tier of columns to properly distribute the load on the foundation. Shoes shall be planed on top.

Sec. 113. *Double Columns.*—In all buildings hereafter erected or altered, where any iron or steel column or columns are used to support a wall or part thereof, whether the same be an exterior or an interior wall, and columns located below the level of the sidewalk which are used to support exterior walls or arches over vaults, the said column or columns shall be either constructed double, that is, an outer and an inner column, the inner column alone to be of sufficient strength to sustain safely the weight to be imposed thereon, and the outer columns shall be one inch shorter than the inner columns, or such other iron or steel column of sufficient strength and protected with not less than two inches of fire-proof material securely applied, except that double or protected columns shall not be required for walls fronting on streets or courts.

Sec. 114. *Party-wall Posts.*—If iron or steel posts are to be used as party posts in front of a party wall, and intended for two buildings, then the said posts shall be not less in width than the thickness of the party wall, nor less in depth than the thickness of the wall to be supported above. Iron or steel posts in front of side, division, or party walls shall be filled up solid with masonry and made perfectly tight between the posts and walls. Intermediate posts may be used, which shall be sufficiently strong, and the lintels thereon shall have sufficient bearings to carry the weight above with safety.

Sec. 115. *Plates between Joints of Open-back Columns.*—Iron or steel posts or columns with one or more open sides and backs shall have solid iron plates on top of each, excepting where pierced for the passage of pipes.

Sec. 116. *Steel and Iron Girders.*—Rivets in flanges shall be spaced so that the least value of a rivet for either shear or bearing is equal or greater than the increment of strain due to the distance between adjoining rivets. All other rules given under riveting shall be followed. The length of rivets between heads shall be limited to four times the diameter. The compression flange of plate girders shall be secured against buckling if its length exceeds thirty times its width. If splices are used, they shall fully make good the members spliced in either tension or compression. Stiffeners shall be provided over supports and under concentrated loads; they shall be of sufficient strength as a column to carry the loads, and shall be connected with a sufficient number of rivets to transmit the stresses into the web plate. Stiffeners shall fit so as to support the flanges of the girders. If the unsupported depth of the web plate exceeds sixty times its thickness, stiffeners shall be used at intervals not exceeding one hundred and twenty times the thickness of the web.

Sec. 117. *Rolled-steel and Wrought-iron Beams Used as Girders.*—When rolled-steel or wrought-iron beams are used in pairs to form a girder, they shall be connected together by bolts and iron separators at intervals of not more than five feet. All beams twelve inches and over in depth shall have at least two bolts to each separator.

Sec. 118. *Cast-iron Lintels.*—Cast-iron lintels shall not be used for spans exceeding sixteen feet. Cast-iron lintels or beams shall be not less than three-quarters of an inch in thickness in any of their parts.

Sec. 119. *Plates under Ends of Lintels and Girders.*—When the lintels or girders are supported at the ends by brick walls or piers they shall rest upon cut-granite or bluestone blocks at least ten inches thick, or upon cast-iron plates of equal strength by the full size of the bearings. In case the opening is less than twelve feet, the stone blocks may be five inches in thickness, or cast-iron plates of equal strength by the full size of the bearings, may be used, provided that in all cases the safe loads do not exceed those fixed by Section 139 of this Code.

Sec. 120. *Rolled-steel and Wrought-iron Floor- and Roof-beams.*—All rolled-steel and wrought-iron floor- and roof-beams used in buildings shall be of full weight, straight and free from injurious defects. Holes for tie-rods shall be placed as near the thrust of the arch as practicable. The distance between tie-rods in floors shall not exceed eight feet, and shall not exceed eight times the depth of floor-beams twelve inches and under. Channels or other shapes, where used as skew-backs, shall have a sufficient resisting moment to take up the thrust of the arch. Bearing plates of stone or metal shall be used to reduce the pressure on the wall to the working stress. Beams resting on girders shall be securely riveted or bolted to the same; where joined on a girder, tie-straps of one-half inch net sectional area shall be used, with rivets or bolts to correspond. Anchors shall be provided at the ends of all such beams bearing on walls.

Sec. 121. *Templates under Ends of Steel or Iron Floor-beams.*—Under the ends of all iron or steel beams where they rest on the walls, a stone or cast-iron template shall be built into the walls. Templates under ends of steel or iron beams shall be of such dimensions as to bring no greater pressure upon the brickwork than that allowed by Section 139 of this Code. When rolled-iron or steel floor-beams, not exceeding six inches in depth, are placed not more than thirty inches on centres, no templates shall be required.

Sec. 122. *Framing and Connecting Structural Work.*—All iron or steel trimmer-beams, headers, and tail-beams, shall be suitably framed and connected together, and the iron or steel girders, columns, beams, trusses, and all other ironwork of all floors and roofs shall be strapped, bolted, anchored, and connected together, and to the walls.

All beams framed into and supported by other beams or girders shall be connected thereto by angles or knees of a

proper size and thickness, and have sufficient bolts or rivets in both legs of each connecting angle to transmit the entire weight or load coming on the beam to the supporting beam or girder. In no case shall the shearing value of the bolts or rivets or the bearing value of the connecting angles, provided for in Section 139 of this Code, be exceeded.

Sec. 123. *Riveting of Structural-steel and Wrought-iron Work.* —The distance from centre of a rivet-hole to the edge of the material shall be not less than

$\frac{5}{8}$ of an inch for $\frac{1}{2}$-inch rivets.
$\frac{7}{8}$ " " " " $\frac{5}{8}$ " "
$1\frac{1}{8}$ " " " " $\frac{3}{4}$ " "
$1\frac{3}{8}$ " " " " $\frac{7}{8}$ " "
$1\frac{1}{2}$ " " " " 1 " "

Wherever possible, however, the distance shall be equal to two diameters. All rivets, wherever practicable, shall be machine-driven. The rivets in connections shall be proportioned and placed to suit the stresses. The pitch of rivets shall never be less than three diameters of the rivet, nor more than six inches. In the direction of the stress it shall not exceed sixteen times the least thickness of the outside member. At right angles to the stress it shall not exceed thirty-two times the least thickness of the outside member. All holes shall be punched accurately, so that upon assembling a cold rivet will enter the hole without straining the material by drifting. Occasional slight errors shall be corrected by reaming. The rivets shall fill the holes completely; the heads shall be hemispherical and concentric with the axis of the rivet. Gussets shall be provided wherever required, of sufficient thickness and size to accommodate the number of rivets necessary to make a connection.

Sec. 124. *Bolting of Structural-steel and Wrought-iron Work* — Where riveting is not made mandatory connections may be effected by bolts. These bolts shall be of wrought iron or mild steel, and they shall have U. S. Standard threads. The threads shall be full and clean, the nut shall be truly concentric with the bolt, and the thread shall be of sufficient length to allow the nut to be screwed up tightly. When bolts go through bevel-flanges, bevel-washers to match shall be used so that head and nut of bolt are parallel. When bolts are used for suspenders, the

working stresses shall be reduced for wrought iron to ten thousand pounds and for steel to fourteen thousand pounds per square inch of net area, and the load shall be transmitted into the head or nut by strong washers distributing the pressure evenly over the entire surface of the same. Turned bolts in reamed holes shall be deemed a substitute for field-rivets.

Sec. 125. *Steel and Wrought-iron Trusses.*—Trusses shall be of such design that the stresses in each member can be calculated. All trusses shall be held rigidly in position by efficient systems of lateral and sway bracing, struts being spaced so that the maximum limit of length to least radius of gyration, established in Section 111 of this Code, is not exceeded. Any member of a truss subjected to transverse stress, in addition to direct tension or compression, shall have the stresses causing such strain added to the direct stresses coming on the member, and the total stresses thus formed shall in no case exceed the working stresses stated in Section 139 of this Code.

Sec. 126. *Riveted-steel and Wrought-iron Trusses.*—For tension members, the actual net area only, after deducting rivet-holes, one-eighth inch larger than the rivets, shall be considered as resisting the stress. If tension members are made of angle-irons riveted through one flange only, only that flange shall be considered in proportioning areas. Rivets to be proportioned as prescribed in Section 123 of this Code. If the axes of two adjoining web members do not intersect within the line of the chords, sufficient area shall be added to the chord to take up the bending strains. No bolts shall be used in the connections of riveted trusses, excepting when riveting is impracticable, and then the holes shall be drilled or reamed.

Sec. 127. *Steel and Iron Pin-connected Trusses.*—The bending stresses on pins shall be limited to twenty thousand pounds for steel and fifteen thousand pounds for iron. All compression members in pin-connected trusses shall be proportioned, using seventy-five per cent of the permissible working stress for columns. The heads of all eye-bars shall be made by upsetting or forging. No weld will be allowed in the body of the bar. Steel eye-bars shall be annealed. Bars shall be straight before boring. All pinholes shall be bored true, and at right angles to the axis of the members, and must fit the pin within one-thirty-second of an inch. The distances of pinholes from centre to centre for corresponding members shall be alike, so that, when piled upon one another, pins will pass through both ends with-

out forcing. Eyes and screw-ends shall be so proportioned that upon test to destruction, fracture will take place in the body of the member. All pins shall be accurately turned. Pin-plates shall be provided wherever necessary to reduce the stresses on pins to the working stresses prescribed in Section 139 of this Code. These pin-plates shall be connected to the members by rivets of sufficient size and number to transmit the stresses without exceeding working stresses. All rivets in members of pin-connected trusses shall be machine-driven. All rivets in pin-plates which are necessary to transmit stress shall be also machine-driven. The main connections of members shall be made by pins. Other connections may be made by bolts. If there is a combination of riveted and pin-connected members in one truss, these members shall comply with the requirements for pin-connected trusses; but the riveting shall comply with the requirements of Section 126 of this Code.

Sec. 128. *Iron and Other Metal Fronts to be Filled In.*—All cast-iron or metal fronts shall be backed up or filled in with masonry of the thicknesses provided for in Sections 31 and 32.

Sec. 129.—*Painting of Structural Metal-work.*—All structural metal-work shall be cleaned of all scale, dirt, and rust, and be thoroughly coated with one coat of paint. Cast-iron columns shall not be painted until after inspection by the Department of Buildings. Where surfaces in riveted work come in contact, they shall be painted before assembling. After erection all work shall be painted at least one additional coat. All iron or steel used under water shall be inclosed with concrete.

SPECIFICATIONS FOR CONSTRUCTIONAL IRON.

1. Character and Finish.—All wrought iron must be tough, ductile, fibrous, and of uniform quality. Finished bars must be thoroughly welded during the rolling, and be straight, smooth, and free from injurious seams, blisters, buckles, cracks, or imperfect edges.

2. Manufacture.—No specific process or provision of manufacture will be demanded, provided the material fulfils the requirements of these specifications.

3. Standard Test-piece.—The tensile strength, limit of elasticity and ductility, shall be determined from a standard test-piece of as near ½-square-inch sectional area as possible. The elongation shall be measured on an original length of 8 inches.

4. Elastic Limit.—Iron of all grades shall have an elastic limit of not less than 26,000 pounds per square inch.

5. High Test or Tension Iron.—When tested in specimens of uniform sectional area of at least ½ square inch, taken from members which have been rolled to a section of not more than 4½ square inches, the iron shall show a minimum ultimate strength of 50,000 pounds per square inch, and a minimum elongation of 18 per cent in 8 inches.

6. Specimens taken from bars of a larger cross-section than 4½ square inches will be allowed a reduction of 500 pounds for each additional square inch of section, down to a minimum of 48,000 pounds, and have an elongation of 15 per cent in 8 inches.

7. Bending Test.—All iron for tension members must bend cold through 90 degrees to a curve whose diameter is not over twice the thickness of the piece, without cracking. At least one sample in three must bend through 180 degrees to this curve, without cracking. When nicked on one side and bent by a blow from a sledge, the fracture must be mostly fibrous.

8. Angle and Other-shaped Iron.—The same-sized specimens taken from angle and other-shaped iron shall have a minimum ultimate strength of 48,000 pounds per square inch, and a minimum elongation of 15 per cent in 8 inches.

9. Specimens from angle and other-shaped iron must bend cold through 90 degrees to a curve whose diameter is not over twice the thickness of the piece, without cracking.

10. Plates.—The same-sized specimens, taken from plates 8 inches to 24 inches in width, shall show a minimum ultimate strength of 48,000 pounds per square inch, and a minimum elongation of 15 per cent in 8 inches; plates from 24 inches to 36 inches wide shall show a minimum ultimate strength of 46,000 pounds per square inch, and elongate 10 per cent in 8 inches; plates over 36 inches wide shall have a minimum elongation of 8 per cent in 8 inches.

11. Samples of plate iron shall stand bending cold through 90 degrees to a curve whose diameter is not over three times its thickness, without cracking. When nicked and bent cold, the fracture must be mostly fibrous.

12. Rivet Iron.—Rivet iron shall have the same physical requirements as high-test iron, and, in addition, shall bend cold 180 degrees to a curve whose diameter is equal to the

thickness of the rod tested, without sign of fracture on the convex side.

13. Pin Iron.—Specimens taken from pin iron under 4 inches diameter shall have a minimum ultimate strength of 50,000 pounds per square inch, and elongate 15 per cent in 8 inches. Rounds over 4 inches diameter, having a minimum elongation of 10 per cent in 8 inches will be satisfactory.

14. Full-size Test.—Full-size pieces of flat, round, or square iron, not over 4½ inches in sectional area, shall have an ultimate strength of 50,000 pounds per square inch, and stretch 12½ per cent in the body of the bar. Bars of a larger sectional area than 4½ square inches will be allowed a reduction of 1000 pounds per square inch, down to a minimum of 46,000 pounds per square inch, and stretch 10 per cent in the body of the bar.

15. Variation in Weight.—The variation in cross-section or weight of rolled material of more than 2½ per cent from that specified may be cause for rejection.

SPECIFICATIONS FOR CONSTRUCTIONAL STEEL.

1. Process of Manufacture.—Steel may be made by either the open-hearth or Bessemer process.

2. Test-pieces.—The tensile strength, limit of elasticity and ductility shall be determined from a standard test-piece cut from the finished material and planed or turned parallel; the piece to have as near ½ square inch sectional area as possible, and elongation to be measured on an original length of 8 inches; two test-pieces to be taken from each heat or blow of finished material, one for tension and one for bending.

3. Every finished piece of steel shall be stamped on one side near the middle with the blow number identifying the melt; and steel for pins shall have the melt number stamped on the ends. Rivet and lacing steel, and small pieces for pin-plates and stiffeners, may be shipped in bundles securely wired together, with the melt number on a metal tag attached.

4. Finish.—Finished bars must be free from injurious seams, flaws, or cracks, and have a workmanlike finish.

5. Grade of Steel.—Steel shall be of three grades: soft, medium, high.

6. Soft Steel.—Specimens from finished material for test, cut to size specified above, shall have an ultimate strength of from

54,000 to 62,000 pounds per square inch; elastic limit one-half the ultimate strength; minimum elongation of 26 per cent in 8 inches; minimum reduction of area at fracture, 50 per cent. This grade of steel to bend cold 180 degrees flat on itself, without sign of fracture on the outside of the bent portion.

7. MEDIUM STEEL.—Specimens from finished material for test, cut to size specified above, shall have an ultimate strength of 60,000 to 68,000 pounds per square inch; elastic limit one-half the ultimate strength; minimum elongation 20 per cent in 8 inches; minimum reduction of area at fracture, 40 per cent. This grade of steel to bend cold 180 degrees to a diameter equal to the thickness of the piece tested, without crack or flaw on the outside of the bent portion.

8. HIGH STEEL.—Specimens from finished material for test, cut to size specified above, shall have an ultimate strength of 66,000 pounds to 74,000 pounds per square inch; elastic limit one-half the ultimate strength; minimum elongation 18 per cent in 8 inches; minimum reduction of area at fracture, 35 per cent. This grade of steel to bend cold 180 degrees to a diameter equal to three times the thickness of the test-piece, without crack or flaw on the outside of the bent portion.

9. PIN STEEL.—Pins made of either of the above-mentioned grades of steel shall, on specimen test-pieces cut from finished material, fill the physical requirements of the grade of steel from which it is rolled, for ultimate strength, elastic limit, and bending, but the elongation shall be decreased 5 per cent, and reduction of area at fracture 10 per cent from that specified.

10. VARIATION IN WEIGHT.—The variation in cross-section or weight of more than $2\frac{1}{2}$ per cent from that specified will be sufficient cause for rejection.

11. FULL-SIZE TESTS OF STEEL BARS.—Full-size tests of steel used for eye-bars shall not be required to show more than 10 per cent elongation in the body of the bar, and tensile strength not more than 4000 pounds below the minimum tensile strength required in specimen tests of the grade of steel from which it is rolled.

SPECIFICATIONS FOR WORKMANSHIP.

1. Inspection.—Inspection of work shall be made as it progresses, and at as early a period as the nature of the work permits.

2. All workmanship must be first-class. All abutting surfaces of compression members, except flanges of plate girders where the joints are fully spliced, must be planed or turned to even bearings so that they shall be in such contact throughout as may be obtained by such means. All finished surfaces must be protected by white lead and tallow.

3. The rivet-holes for splice plates of abutting members shall be so accurately spaced that when the members are brought into position the holes shall be truly opposite before the rivets are driven.

4. Rollers must be finished perfectly round and roller-beds planed.

5. Rivets.—The pitch of rivets in all classes of work shall never exceed 6 in., nor 16 times the thinnest outside plate, nor be less than 3 diameters of the rivet. The rivets used shall generally be $\frac{5}{8}$, $\frac{3}{4}$, and $\frac{7}{8}$ in. diameter. The distance between the edge of any piece and the centre of a rivet-hole must never be less than $1\frac{1}{4}$ in., except for bars less than $2\frac{1}{2}$ in. wide. When practicable it shall be at least 2 diameters of the rivet. Rivets must completely fill the holes, have full heads concentric with the rivet, of a height not less than .6 the diameter of the rivet, and in full contact with the surface, or be countersunk when so required, and machine-driven wherever practicable.

6. Punching.—The diameter of the punch shall not exceed by more than $\frac{1}{16}$ in. the diameter of the rivets to be used, and all holes must be clean cuts, without torn or ragged edges. Rivet-holes must be accurately spaced; the use of drift-pins will be allowed only for bringing together the several parts forming a member, and they must not be driven with such force as to disturb the metal about the holes.

7. Built members must, when finished, be true and free from twists, kinks, buckles, or open joints between the component pieces.

8. Eye-bars and Pinholes.—All pinholes must be accurately bored at right angles to the axis of the members, unless

otherwise shown in the drawings, and in pieces not adjustable for length no variation of more than $\frac{1}{32}$ of an inch will be allowed in the length between centres of pinholes; the diameter of the pinholes shall not exceed that of the pins by more than $\frac{1}{32}$ in., nor by more than $\frac{1}{50}$ in. for pins under $3\frac{1}{2}$ in. diameter. Eye-bars must be straight before boring; the holes must be in the centre of the heads, and on the centre line of the bars. Whenever eye-bars are to be packed more than $\frac{1}{8}$ of an inch to the foot of their length out of parallel with the axis of the structure, they must be bent with a gentle curve until the head stands at right angles to the pin in their intended positions before being bored. All eye-bars belonging to the same panel, when placed in a pile, must allow the pin at each end to pass through at the same time without forcing. No welds will be allowed in the body of the bar of eye-bars, laterals, or counters, except to form the loops of laterals, counters, and sway-rods; eyes of laterals, stirrups, sway-rods, and counters must be bored.

Pilot-nuts.—Pins and lateral bolts must be finished perfectly round and straight, and the party contracting to erect the work must provide pilot-nuts where necessary to preserve the threads while the pins are being driven. Thimbles or washers must be used whenever required to fill the vacant spaces on pins or bolts.

9. Annealing.—In all cases where a steel piece in which the full strength is required has been partially heated the whole piece must be subsequently annealed. All bends in steel must be made cold, or if the degree of curvature is so great as to require heating, the whole piece must be subsequently annealed.

10. Painting.—All surfaces inaccessible after assembling must be well painted or oiled before the parts are assembled.

11. The decision of the engineer shall control as to the interpretation of drawings and specifications during the execution of work thereunder, but this shall not deprive the contractor of his right to redress, after the completion of the work, for an improper decision.

Notes on Steel and Iron.—1. The average weight of wrought iron is 480 lbs. per cubic foot. A bar 1 inch square and 3 feet long weighs, therefore, exactly 10 lbs. Hence:

To find the sectional area, given the weight per foot, multiply by 0.3.

To find the weight per foot, given the sectional area, multiply by $\frac{10}{3}$.

2. The weight of steel is 2 per cent greater than that of wrought iron.

To find sectional area, given weight per foot, divide by 3.4.

To find weight per foot, given sectional area, multiply by 3.4.

3. The centre load at which a bar of wrought iron 1 in. square and 12 ins. centre to centre of points of support will give way is very nearly *one ton* (of 2240 lbs.).

4. Within the elastic limit the extension and compression of wrought iron is very nearly one ten-thousandth of its length for a stress of *one ton* (of 2240 lbs.) per square inch.

For cast iron this ratio is one five-thousandth for tension, but becomes variable for compression.

5. The contraction or expansion of wrought iron under changes of temperature is about one ten-thousandth of its length for a variation of 15° Fahr.

The stress thus induced, if the ends are held rigidly fixed, will be about *one ton* (of 2240 lbs.) per square inch of cross-section.

6. The coefficient of expansion of wrought iron for 100° Fahr. is 0.000686. Therefore for a variation in temperature of 125°, a bar of wrought iron 100 feet long will expand or contract 1.029 inches.

Conversely, a change in length of 1 inch per hundred feet would be produced by a variation in temperature of 121.5° Fahr.

7. The melting-point of iron and steel is about as follows:

Wrought iron	3000° Fahr.
Cast iron.	2000° "
Steel.	2400° "

8. The welding heat of wrought iron is 2733° Fahr.

Miscellaneous Notes.—1. Thrust of arch per lineal foot

$$T = \frac{1.5wl^2}{r},$$

in which w = load per square foot, r = rise in arch in inches, and l = span in feet.

2. Approximately the radius of gyration for a box section is four-tenths the least side.

The working strength of iron and steel as given by the Chicago Building Code is as follows:

STRESSES—CAST-IRON FIBRE—STRAINS—LENGTH.

Sec. 92. The stresses in materials hereafter used in construction, produced by the calculated strains due to their own weight and applied loads, shall in no case exceed the following:

Cast iron:	Extreme fibre strains tension........	2,500 lbs.
	For columns........................	10,000 "

Reduced by Gordon's formula. Reduced for eccentric load.

No cast-iron column shall have a length to exceed twenty times its diameter or least side.

Stresses in Pounds per Square Inch.

	Wrought Iron.	Steel.
Extreme fibre stresses, I beams and shapes....	12,000	16,000
Extreme fibre stresses, built beams...........	10,000	15,000
Tension................................	12,000	15,000
Shearing................................	7,500	10,000
Direct-bearing pins and rivets...............	15,000	20,000
Bending on pins..........................	18,000	22,500
* For columns and compression members......	12,000	15,000

* Reduced for ratio of length of column to its least radius of gyration by approved modern formulæ. Reduced for eccentric load.

WEIGHTS OF FLAT ROLLED STEEL.

Per Lineal Foot.

One Cubic Foot Weighing 489.6 Lbs.

Thickness in Inches.	1″	1¼″	1½″	1¾″	2″	2¼″	2½″	2¾″	12″
3/16	.638	.797	.957	1.11	1.28	1.44	1.59	1.75	7.65
1/4	.850	1.06	1.28	1.49	1.70	1.91	2.12	2.34	10.20
5/16	1.06	1.33	1.59	1.86	2.12	2.39	2.65	2.92	12.75
3/8	1.28	1.59	1.92	2.23	2.55	2.87	3.19	3.51	15.30
7/16	1.49	1.86	2.23	2.60	2.98	3.35	3.72	4.09	17.85
1/2	1.70	2.12	2.55	2.98	3.40	3.83	4.25	4.67	20.40
9/16	1.92	2.39	2.87	3.35	3.83	4.30	4.78	5.26	22.95
5/8	2.12	2.65	3.19	3.72	4.25	4.78	5.31	5.84	25.50
11/16	2.34	2.92	3.51	4.09	4.67	5.26	5.84	6.43	28.05
3/4	2.55	3.19	3.83	4.47	5.10	5.75	6.38	7.02	30.60
13/16	2.76	3.45	4.14	4.84	5.53	6.21	6.90	7.60	33.15
7/8	2.98	3.72	4.47	5.20	5.95	6.69	7.44	8.18	35.70
15/16	3.19	3.99	4.78	5.58	6.38	7.18	7.97	8.77	38.25
1	3.40	4.25	5.10	5.95	6.80	7.65	8.50	9.35	40.80
1 1/16	3.61	4.52	5.42	6.32	7.22	8.13	9.03	9.93	43.35
1 1/8	3.83	4.78	5.74	6.70	7.65	8.61	9.57	10.52	45.90
1 3/16	4.04	5.05	6.06	7.07	8.08	9.09	10.10	11.11	48.45
1 1/4	4.25	5.31	6.38	7.44	8.50	9.57	10.63	11.69	51.00
1 5/16	4.46	5.58	6.69	7.81	8.93	10.04	11.16	12.27	53.55
1 3/8	4.67	5.84	7.02	8.18	9.35	10.52	11.69	12.85	56.10
1 7/16	4.89	6.11	7.34	8.56	9.78	11.00	12.22	13.44	58.65
1 1/2	5.10	6.38	7.65	8.93	10.20	11.48	12.75	14.03	61.20
1 9/16	5.32	6.64	7.97	9.30	10.63	11.95	13.28	14.61	63.75
1 5/8	5.52	6.90	8.29	9.67	11.05	12.43	13.81	15.19	66.30
1 11/16	5.74	7.17	8.61	10.04	11.47	12.91	14.34	15.78	68.85
1 3/4	5.95	7.44	8.93	10.42	11.90	13.40	14.88	16.37	71.40
1 13/16	6.16	7.70	9.24	10.79	12.33	13.86	15.40	16.95	73.95
1 7/8	6.38	7.97	9.57	11.15	12.75	14.34	15.94	17.53	76.50
1 15/16	6.59	8.24	9.88	11.53	13.18	14.83	16.47	18.12	79.05
2	6.80	8.50	10.20	11.90	13.60	15.30	17.00	18.70	81.60

WEIGHTS OF FLAT ROLLED STEEL—(*Continued*).

PER LINEAL FOOT.

Thickness in Inches.	3″	3¼″	3½″	3¾″	4″	4¼″	4½″	4¾″	12″
$\frac{3}{16}$	1.91	2.07	2.23	2.39	2.55	2.71	2.87	3.03	7.65
$\frac{1}{4}$	2.55	2.76	2.98	3.19	3.40	3.61	3.83	4.04	10.20
$\frac{5}{16}$	3.19	3.45	3.72	3.99	4.25	4.52	4.78	5.05	12.75
$\frac{3}{8}$	3.83	4.15	4.47	4.78	5.10	5.42	5.74	6.06	15.30
$\frac{7}{16}$	4.46	4.83	5.20	5.58	5.95	6.32	6.70	7.07	17.85
$\frac{1}{2}$	5.10	5.53	5.95	6.38	6.80	7.22	7.65	8.08	20.40
$\frac{9}{16}$	5.74	6.22	6.70	7.17	7.65	8.13	8.61	9.09	22.95
$\frac{5}{8}$	6.38	6.91	7.44	7.97	8.50	9.03	9.57	10.10	25.50
$\frac{11}{16}$	7.02	7.60	8.18	8.76	9.35	9.93	10.52	11.11	28.05
$\frac{3}{4}$	7.65	8.29	8.93	9.57	10.20	10.84	11.48	12.12	30.60
$\frac{13}{16}$	8.29	8.98	9.67	10.36	11.05	11.74	12.43	13.12	33.15
$\frac{7}{8}$	8.93	9.67	10.41	11.16	11.90	12.65	13.39	14.13	35.70
$\frac{15}{16}$	9.57	10.36	11.16	11.95	12.75	13.55	14.34	15.14	38.25
1	10.20	11.05	11.90	12.75	13.60	14.45	15.30	16.15	40.80
$1\frac{1}{16}$	10.84	11.74	12.65	13.55	14.45	15.35	16.26	17.16	43.35
$1\frac{1}{8}$	11.48	12.43	13.39	14.34	15.30	16.26	17.22	18.17	45.90
$1\frac{3}{16}$	12.12	13.12	14.13	15.14	16.15	17.16	18.17	19.18	48.45
$1\frac{1}{4}$	12.75	13.81	14.87	15.94	17.00	18.06	19.13	20.19	51.00
$1\frac{5}{16}$	13.39	14.50	15.62	16.74	17.85	18.96	20.08	21.20	53.55
$1\frac{3}{8}$	14.03	15.20	16.36	17.53	18.70	19.87	21.04	22.21	56.10
$1\frac{7}{16}$	14.66	15.88	17.10	18.33	19.55	20.77	21.99	23.22	58.65
$1\frac{1}{2}$	15.30	16.58	17.85	19.13	20.40	21.68	22.95	24.23	61.20
$1\frac{9}{16}$	15.94	17.27	18.60	19.92	21.25	22.58	23.91	25.24	63.75
$1\frac{5}{8}$	16.58	17.96	19.34	20.72	22.10	23.48	24.87	26.25	66.30
$1\frac{11}{16}$	17.22	18.65	20.08	21.51	22.95	24.38	25.82	27.26	68.85
$1\frac{3}{4}$	17.85	19.34	20.83	22.32	23.80	25.29	26.78	28.27	71.40
$1\frac{13}{16}$	18.49	20.03	21.57	23.11	24.65	26.19	27.73	29.27	73.95
$1\frac{7}{8}$	19.13	20.72	22.31	23.91	25.50	27.10	28.69	30.28	76.50
$1\frac{15}{16}$	19.77	21.41	23.06	24.70	26.35	28.00	29.64	31.29	79.05
2	20.40	22.10	23.80	25.50	27.20	28.90	30.60	32.30	81.60

WEIGHTS OF FLAT ROLLED STEEL—(*Continued*).

PER LINEAL FOOT.

Thickness in Inches.	5″	5¼″	5½″	5¾″	6″	6¼″	6½″	6¾″	12″
3/16	3.19	3.35	3.51	3.67	3.83	3.99	4.14	4.30	7.65
1/4	4.25	4.46	4.67	4.89	5.10	5.31	5.53	5.74	10.20
5/16	5.31	5.58	5.84	6.11	6.38	6.64	6.90	7.17	12.75
3/8	6.38	6.69	7.02	7.34	7.65	7.97	8.29	8.61	15.30
7/16	7.44	7.81	8.18	8.56	8.93	9.29	9.67	10.04	17.85
1/2	8.50	8.93	9.35	9.77	10.20	10.63	11.05	11.48	20.40
9/16	9.57	10.04	10.52	11.00	11.48	11.95	12.43	12.91	22.95
5/8	10.63	11.16	11.69	12.22	12.75	13.28	13.81	14.34	25.50
11/16	11.69	12.27	12.85	13.44	14.03	14.61	15.20	15.78	28.05
3/4	12.75	13.39	14.03	14.67	15.30	15.94	16.58	17.22	30.60
13/16	13.81	14.50	15.19	15.88	16.58	17.27	17.95	18.65	33.15
7/8	14.87	15.62	16.36	17.10	17.85	18.60	19.34	20.08	35.70
15/16	15.94	16.74	17.53	18.33	19.13	19.92	20.72	21.51	38.25
1	17.00	17.85	18.70	19.55	20.40	21.25	22.10	22.95	40.80
1 1/16	18.06	18.96	19.87	20.77	21.68	22.58	23.48	24.39	43.35
1 1/8	19.13	20.08	21.04	21.99	22.95	23.91	24.87	25.82	45.90
1 3/16	20.19	21.20	22.21	23.22	24.23	25.23	26.24	27.25	48.45
1 1/4	21.25	22.32	23.38	24.44	25.50	26.56	27.62	28.69	51.00
1 5/16	22.32	23.43	24.54	25.66	26.78	27.90	29.01	30.12	53.55
1 3/8	23.38	24.54	25.71	26.88	28.05	29.22	30.39	31.56	56.10
1 7/16	24.44	25.66	26.88	28.10	29.33	30.55	31.77	32.99	58.65
1 1/2	25.50	26.78	28.05	29.33	30.60	31.88	33.15	34.43	61.20
1 9/16	26.57	27.89	29.22	30.55	31.88	33.20	34.53	35.86	63.75
1 5/8	27.63	29.01	30.39	31.77	33.15	34.53	35.91	37.29	66.30
1 11/16	28.69	30.12	31.55	32.99	34.43	35.86	37.30	38.73	68.85
1 3/4	29.75	31.24	32.73	34.22	35.70	37.19	38.68	40.17	71.40
1 13/16	30.81	32.35	33.89	35.43	36.98	38.52	40.05	41.60	73.95
1 7/8	31.87	33.47	35.06	36.65	38.25	39.85	41.44	43.03	76.50
1 15/16	32.94	34.59	36.23	37.88	39.53	41.17	42.82	44.46	79.05
2	34.00	35.70	37.40	39.10	40.80	42.50	44.20	45.90	81.60

WEIGHTS OF FLAT ROLLED STEEL—(*Continued*).

PER LINEAL FOOT.

Thickness in Inches.	7″	7¼″	7½″	7¾″	8″	8¼″	8½″	8¾″	12″
3/16	4.46	4.62	4.78	4.94	5.10	5.26	5.42	5.58	7.65
¼	5.95	6.16	6.36	6.58	6.80	7.01	7.22	7.43	10.20
5/16	7.44	7.70	7.97	8.23	8.50	8.76	9.03	9.29	12.75
⅜	8.93	9.25	9.57	9.88	10.20	10.52	10.84	11.16	15.30
7/16	10.41	10.78	11.16	11.53	11.90	12.27	12.64	13.02	17.85
½	11.90	12.32	12.75	13.18	13.60	14.03	14.44	14.87	20.40
9/16	13.39	13.86	14.34	14.82	15.30	15.78	16.26	16.74	22.95
⅝	14.87	15.40	15.94	16.47	17.00	17.53	18.06	18.59	25.50
11/16	16.36	16.94	17.53	18.12	18.70	19.28	19.86	20.45	28.05
¾	17.85	18.49	19.13	19.77	20.40	21.04	21.68	22.32	30.60
13/16	19.34	20.03	20.72	21.41	22.10	22.79	23.48	24.17	33.15
⅞	20.83	21.57	22.32	23.05	23.80	24.55	25.30	26.04	35.70
15/16	22.32	23.11	23.91	24.70	25.50	26.30	27.10	27.89	38.25
1	23.80	24.65	25.50	26.35	27.20	28.05	28.90	29.75	40.80
1 1/16	25.29	26.19	27.10	28.00	28.90	29.80	30.70	31.61	43.35
1⅛	26.78	27.73	28.68	29.64	30.60	31.56	32.52	33.47	45.90
1 3/16	28.26	29.27	30.28	31.29	32.30	33.31	34.32	35.33	48.45
1¼	29.75	30.81	31.88	32.94	34.00	35.06	36.12	37.20	51.00
1 5/16	31.23	32.35	33.48	34.59	35.70	36.81	37.93	39.05	53.55
1⅜	32.72	33.89	35.06	36.23	37.40	38.57	39.74	40.91	56.10
1 7/16	34.21	35.44	36.66	37.88	39.10	40.32	41.54	42.77	58.65
1½	35.70	36.98	38.26	39.53	40.80	42.08	43.35	44.63	61.20
1 9/16	37.19	38.51	39.84	41.17	42.50	43.83	45.16	46.49	63.75
1⅝	38.67	40.05	41.44	42.82	44.20	45.58	46.96	48.34	66.30
1 11/16	40.16	41.59	43.03	44.47	45.90	47.33	48.76	50.20	68.85
1¾	41.65	43.14	44.63	46.12	47.60	49.09	50.58	52.07	71.40
1 13/16	43.14	44.68	46.22	47.76	49.30	50.84	52.38	53.92	73.95
1⅞	44.63	46.22	47.82	49.40	51.00	52.60	54.20	55.79	76.50
1 15/16	46.12	47.76	49.41	51.05	52.70	54.35	56.00	57.64	79.05
2	47.60	49.30	51.00	52.70	54.40	56.10	57.80	59.50	81.60

WEIGHTS OF FLAT ROLLED STEEL—(*Continued*).

PER LINEAL FOOT.

Thickness in Inches.	9"	9¼"	9½"	9¾"	10"	10¼"	10½"	10¾"	12"
3/16	5.74	5.90	6.06	6.22	6.38	6.54	6.70	6.86	7.65
1/4	7.65	7.86	8.08	8.29	8.50	8.71	8.92	9.14	10.20
5/16	9.56	9.83	10.10	10.36	10.62	10.89	11.16	11.42	12.75
3/8	11.48	11.80	12.12	12.44	12.75	13.07	13.39	13.71	15.30
7/16	13.40	13.76	14.14	14.51	14.88	15.25	15.62	15.99	17.85
1/2	15.30	15.73	16.16	16.58	17.00	17.42	17.85	18.28	20.40
9/16	17.22	17.69	18.18	18.65	19.14	19.61	20.08	20.56	22.95
5/8	19.13	19.65	20.19	20.72	21.25	21.78	22.32	22.85	25.50
11/16	21.04	21.62	22.21	22.79	23.38	23.96	24.54	25.13	28.05
3/4	22.96	23.59	24.23	24.86	25.50	26.14	26.78	27.42	30.60
13/16	24.86	25.55	26.24	26.94	27.62	28.32	29.00	29.69	33.15
7/8	26.78	27.52	28.26	29.01	29.75	30.50	31.24	31.98	35.70
15/16	28.69	29.49	30.28	31.08	31.88	32.67	33.48	34.28	38.25
1	30.60	31.45	32.30	33.15	34.00	34.85	35.70	36.55	40.80
1 1/16	32.52	33.41	34.32	35.22	36.12	37.03	37.92	38.83	43.35
1 1/8	34.43	35.38	36.34	37.29	38.25	39.21	40.17	41.12	45.90
1 3/16	36.34	37.35	38.36	39.37	40.38	41.39	42.40	43.40	48.45
1 1/4	38.26	39.31	40.37	41.44	42.50	43.56	44.63	45.69	51.00
1 5/16	40.16	41.28	42.40	43.52	44.64	45.75	46.86	47.97	53.55
1 3/8	42.08	43.25	44.41	45.58	46.75	47.92	49.08	50.25	56.10
1 7/16	44.00	45.22	46.44	47.66	48.88	50.10	51.32	52.54	58.65
1 1/2	45.90	47.18	48.45	49.73	51.00	52.28	53.55	54.83	61.20
1 9/16	47.82	49.14	50.48	51.80	53.14	54.46	55.78	57.11	63.75
1 5/8	49.73	51.10	52.49	53.87	55.25	56.63	58.02	59.40	66.30
1 11/16	51.64	53.07	54.51	55.94	57.38	58.81	60.24	61.68	68.85
1 3/4	53.56	55.04	56.53	58.01	59.50	60.99	62.48	63.97	71.40
1 13/16	55.46	57.00	58.54	60.09	61.62	63.17	64.70	66.24	73.95
1 7/8	57.38	58.97	60.56	62.16	63.75	65.35	66.94	68.53	76.50
1 15/16	59.29	60.94	62.58	64.23	65.88	67.52	69.18	70.83	79.05
2	61.20	62.90	64.60	66.30	68.00	69.70	71.40	73.10	81.60

WEIGHTS OF FLAT ROLLED STEEL—(*Continued*).

PER LINEAL FOOT.

Thickness in Inches.	11″	11¼″	11½″	11¾″	12″	12¼″	12½″	12¾″
$\frac{3}{16}$	7.02	7.17	7.32	7.49	7.65	7.82	7.98	8.13
$\frac{1}{4}$	9.34	9.57	9.78	10.00	10.20	10.42	10.63	10.84
$\frac{5}{16}$	11.68	11.95	12.22	12.49	12.75	13.01	13.28	13.55
$\frac{3}{8}$	14.03	14.35	14.68	14.99	15.30	15.62	15.94	16.26
$\frac{7}{16}$	16.36	16.74	17.12	17.49	17.85	18.23	18.60	18.97
$\frac{1}{2}$	18.70	19.13	19.55	19.97	20.40	20.82	21.25	21.67
$\frac{9}{16}$	21.02	21.51	22.00	22.48	22.95	23.43	23.90	24.39
$\frac{5}{8}$	23.38	23.91	24.44	24.97	25.50	26.03	26.56	27.09
$\frac{11}{16}$	25.70	26.30	26.88	27.47	28.05	28.64	29.22	29.80
$\frac{3}{4}$	28.05	28.68	29.33	29.97	30.60	31.25	31.88	32.52
$\frac{13}{16}$	30.40	31.08	31.76	32.46	33.15	33.83	34.53	35.22
$\frac{7}{8}$	32.72	33.47	34.21	34.95	35.70	36.44	37.19	37.93
$\frac{15}{16}$	35.06	35.86	36.66	37.46	38.25	39.05	39.84	40.64
1	37.40	38.25	39.10	39.95	40.80	41.65	42.50	43.35
$1\frac{1}{16}$	39.74	40.64	41.54	42.54	43.35	44.25	45.16	46.06
$1\frac{1}{8}$	42.08	43.04	44.00	44.94	45.90	46.86	47.82	48.77
$1\frac{3}{16}$	44.42	45.42	46.44	47.45	48.45	49.46	50.46	51.48
$1\frac{1}{4}$	46.76	47.82	48.88	49.94	51.00	52.06	53.12	54.19
$1\frac{5}{16}$	49.08	50.20	51.32	52.44	53.55	54.67	55.78	56.90
$1\frac{3}{8}$	51.42	52.59	53.76	54.93	56.10	57.27	58.44	59.60
$1\frac{7}{16}$	53.76	54.99	56.21	57.43	58.65	59.87	60.10	62.32
$1\frac{1}{2}$	56.10	57.37	58.65	59.93	61.20	62.48	63.75	65.03
$1\frac{9}{16}$	58.42	59.76	61.10	62.43	63.75	65.08	66.40	67.74
$1\frac{5}{8}$	60.78	62.16	63.54	64.92	66.30	67.68	69.06	70.44
$1\frac{11}{16}$	63.10	64.55	65.98	67.42	68.85	70.29	71.72	73.15
$1\frac{3}{4}$	65.45	66.93	68.43	69.92	71.40	72.90	74.38	75.87
$1\frac{13}{16}$	67.80	69.33	70.86	72.41	73.95	75.48	77.03	78.57
$1\frac{7}{8}$	70.12	71.72	73.31	74.90	76.50	78.09	79.69	81.28
$1\frac{15}{16}$	72.46	74.11	75.76	77.41	79.05	80.70	82.34	83.99
2	74.80	76.50	78.20	79.90	81.60	83.30	85.00	86.70

The weights for 12-inch width are repeated on each page to facilitate making the additions necessary to obtain the weights of plates wider than 12 inches. Thus, to find the weight of $15\frac{1}{4} \times \frac{7}{8}$ in. add the weights to be found in the same line for $3\frac{1}{4} \times \frac{7}{8}$ and $12 \times \frac{7}{8} = 10.41 + 35.70 = 46.11$ lbs.

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS.

One cubic foot of steel weighing 489.6 lbs.

Thickness or Diameter in Inches.	Weight of □ Bar One Foot Long.	Weight of ○ Bar One Foot Long.	Area of □ Bar in Square Inches.	Area of ○ Bar in Square Inches.	Circumference of ○ Bar in Inches.
0					
$\frac{1}{16}$	.013	.010	.0039	.0031	.1963
$\frac{1}{8}$	.053	.042	.0156	.0123	.3927
$\frac{3}{16}$	.119	.094	.0352	.0276	.5890
$\frac{1}{4}$	.212	.167	.0625	.0491	.7854
$\frac{5}{16}$	.333	.261	.0977	.0767	.9817
$\frac{3}{8}$	.478	.375	.1406	.1104	1.1781
$\frac{7}{16}$	.651	.511	.1914	.1503	1.3744
$\frac{1}{2}$	.850	.667	.2500	.1963	1.5708
$\frac{9}{16}$	1.076	.845	.3164	.2485	1.7671
$\frac{5}{8}$	1.328	1.043	.3906	.3068	1.9635
$\frac{11}{16}$	1.608	1.262	.4727	.3712	2.1598
$\frac{3}{4}$	1.913	1.502	.5625	.4418	2.3562
$\frac{13}{16}$	2.245	1.763	.6602	.5185	2.5525
$\frac{7}{8}$	2.603	2.044	.7656	.6013	2.7489
$\frac{15}{16}$	2.989	2.347	.8789	.6903	2.9452
1	3.400	2.670	1.0000	.7854	3.1416
$\frac{1}{16}$	3.838	3.014	1.1289	.8866	3.3379
$\frac{1}{8}$	4.303	3.379	1.2656	.9940	3.5343
$\frac{3}{16}$	4.795	3.766	1.4102	1.1075	3.7306
$\frac{1}{4}$	5.312	4.173	1.5625	1.2272	3.9270
$\frac{5}{16}$	5.857	4.600	1.7227	1.3530	4.1233
$\frac{3}{8}$	6.428	5.049	1.8906	1.4849	4.3197
$\frac{7}{16}$	7.026	5.518	2.0664	1.6230	4.5160
$\frac{1}{2}$	7.650	6.008	2.2500	1.7671	4.7124
$\frac{9}{16}$	8.301	6.520	2.4414	1.9175	4.9087
$\frac{5}{8}$	8.978	7.051	2.6406	2.0739	5.1051
$\frac{11}{16}$	9.682	7.604	2.8477	2.2365	5.3014
$\frac{3}{4}$	10.41	8.178	3.0625	2.4053	5.4978
$\frac{13}{16}$	11.17	8.773	3.2852	2.5802	5.6941
$\frac{7}{8}$	11.95	9.388	3.5156	2.7612	5.8905
$\frac{15}{16}$	12.76	10.02	3.7539	2.9483	6.0868

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS—(*Continued*).

Thickness or Diameter in Inches.	Weight of □ Bar One Foot Long.	Weight of ○ Bar One Foot Long.	Area of □ Bar in Square Inches.	Area of ○ Bar in Square Inches.	Circumference of ○ Bar in Inches.
2	13.60	10.68	4.0000	3.1416	6.2832
$\frac{1}{16}$	14.46	11.36	4.2539	3.3410	6.4795
$\frac{1}{8}$	15.35	12.06	4.5156	3.5466	6.6759
$\frac{3}{16}$	16.27	12.78	4.7852	3.7583	6.8722
$\frac{1}{4}$	17.22	13.52	5.0625	3.9761	7.0686
$\frac{5}{16}$	18.19	14.28	5.3477	4.2000	7.2649
$\frac{3}{8}$	19.18	15.07	5.6406	4.4301	7.4613
$\frac{7}{16}$	20.20	15.86	5.9414	4.6664	7.6576
$\frac{1}{2}$	21.25	16.69	6.2500	4.9087	7.8540
$\frac{9}{16}$	22.33	17.53	6.5664	5.1572	8.0503
$\frac{5}{8}$	23.43	18.40	6.8906	5.4119	8.2467
$\frac{11}{16}$	24.56	19.29	7.2227	5.6727	8.4430
$\frac{3}{4}$	25.71	20.20	7.5625	5.9396	8.6394
$\frac{13}{16}$	26.90	21.12	7.9102	6.2126	8.8357
$\frac{7}{8}$	28.10	22.07	8.2656	6.4918	9.0321
$\frac{15}{16}$	29.34	23.04	8.6289	6.7771	9.2284
3	30.60	24.03	9.0000	7.0686	9.4248
$\frac{1}{16}$	31.89	25.04	9.3789	7.3662	9.6211
$\frac{1}{8}$	33.20	26.08	9.7656	7.6699	9.8175
$\frac{3}{16}$	34.55	27.13	10.160	7.9798	10.014
$\frac{1}{4}$	35.92	28.20	10.563	8.2958	10.210
$\frac{5}{16}$	37.31	29.30	10.973	8.6179	10.407
$\frac{3}{8}$	38.73	30.42	11.391	8.9462	10.603
$\frac{7}{16}$	40.18	31.56	11.816	9.2806	10.799
$\frac{1}{2}$	41.65	32.71	12.250	9.6211	10.996
$\frac{9}{16}$	43.14	33.90	12.691	9.9678	11.192
$\frac{5}{8}$	44.68	35.09	13.141	10.321	11.388
$\frac{11}{16}$	46.24	36.31	13.598	10.680	11.585
$\frac{3}{4}$	47.82	37.56	14.063	11.045	11.781
$\frac{13}{16}$	49.42	38.81	14.535	11.416	11.977
$\frac{7}{8}$	51.05	40.10	15.016	11.793	12.174
$\frac{15}{16}$	52.71	41.40	15.504	12.177	12.370

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS—(*Continued*).

Thickness or Diameter in Inches.	Weight of □ Bar One Foot Long.	Weight of ○ Bar One Foot Long.	Area of □ Bar in Square Inches.	Area of ○ Bar in Square Inches.	Circumference of ○ Bar in Inches.
4	54.40	42.73	16.000	12.566	12.566
$\frac{1}{16}$	56.11	44.07	16.504	12.962	12.763
$\frac{1}{8}$	57.85	45.44	17.016	13.364	12.959
$\frac{3}{16}$	59.62	46.83	17.535	13.772	13.155
$\frac{1}{4}$	61.41	48.24	18.063	14.186	13.352
$\frac{5}{16}$	63.23	49.66	18.598	14.607	13.548
$\frac{3}{8}$	65.08	51.11	19.141	15.033	13.744
$\frac{7}{16}$	66.95	52.58	19.691	15.466	13.941
$\frac{1}{2}$	68.85	54.07	20.250	15.904	14.137
$\frac{9}{16}$	70.78	55.59	20.816	16.349	14.334
$\frac{5}{8}$	72.73	57.12	21.391	16.800	14.530
$\frac{11}{16}$	74.70	58.67	21.973	17.257	14.726
$\frac{3}{4}$	76.71	60.25	22.563	17.721	14.923
$\frac{13}{16}$	78.74	61.84	23.160	18.190	15.119
$\frac{7}{8}$	80.81	63.46	23.766	18.665	15.315
$\frac{15}{16}$	82.89	65.10	24.379	19.147	15.512
5	85.00	66.76	25.000	19.635	15.708
$\frac{1}{16}$	87.14	68.44	25.629	20.129	15.904
$\frac{1}{8}$	89.30	70.14	26.266	20.629	16.101
$\frac{3}{16}$	91.49	71.86	26.910	21.135	16.297
$\frac{1}{4}$	93.72	73.60	27.563	21.648	16.493
$\frac{5}{16}$	95.96	75.37	28.223	22.166	16.690
$\frac{3}{8}$	98.23	77.15	28.891	22.691	16.886
$\frac{7}{16}$	100.5	78.95	29.566	23.221	17.082
$\frac{1}{2}$	102.8	80.77	30.250	23.758	17.279
$\frac{9}{16}$	105.2	82.62	30.941	24.301	17.475
$\frac{5}{8}$	107.6	84.49	31.641	24.850	17.671
$\frac{11}{16}$	110.0	86.38	32.348	25.406	17.868
$\frac{3}{4}$	112.4	88.29	33.063	25.967	18.064
$\frac{13}{16}$	114.9	90.22	33.785	26.535	18.261
$\frac{7}{8}$	117.4	92.17	34.516	27.109	18.457
$\frac{15}{16}$	119.9	94.14	35.254	27.688	18.653

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS—(*Continued*).

Thickness or Diameter in Inches.	Weight of □ Bar One Foot Long	Weight of ○ Bar One Foot Long.	Area of □ Bar in Square Inches.	Area of ○ Bar in Square Inches.	Circumference of ○ Bar in Inches.
6	122.4	96.14	36.000	28.274	18.850
$\frac{1}{16}$	125.0	98.14	36.754	28.866	19.046
$\frac{1}{8}$	127.6	100.2	37.516	29.465	19.242
$\frac{3}{16}$	130.2	102.2	38.285	30.069	19.439
$\frac{1}{4}$	132.8	104.3	39.063	30.680	19.635
$\frac{5}{16}$	135.5	106.4	39.848	31.296	19.831
$\frac{3}{8}$	138.2	108.5	40.641	31.919	20.028
$\frac{7}{16}$	140.9	110.7	41.441	32.548	20.224
$\frac{1}{2}$	143.6	112.8	42.250	33.183	20.420
$\frac{9}{16}$	146.5	114.9	43.066	33.824	20.617
$\frac{5}{8}$	149.2	117.2	43.891	34.472	20.813
$\frac{11}{16}$	152.1	119.4	44.723	35.125	21.009
$\frac{3}{4}$	154.9	121.7	45.563	35.785	21.206
$\frac{13}{16}$	157.8	123.9	46.410	36.450	21.402
$\frac{7}{8}$	160.8	126.2	47.266	37.122	21.598
$\frac{15}{16}$	163.6	128.5	48.129	37.800	21.795
7	166.6	130.9	49.000	38.485	21.991
$\frac{1}{16}$	169.6	133.2	49.879	39.175	22.187
$\frac{1}{8}$	172.6	135.6	50.766	39.871	22.384
$\frac{3}{16}$	175.6	137.9	51.660	40.574	22.580
$\frac{1}{4}$	178.7	140.4	52.563	41.282	22.777
$\frac{5}{16}$	181.8	142.8	53.473	41.997	22.973
$\frac{3}{8}$	184.9	145.3	54.391	42.718	23.169
$\frac{7}{16}$	188.1	147.7	55.316	43.445	23.366
$\frac{1}{2}$	191.3	150.2	56.250	44.179	23.562
$\frac{9}{16}$	194.4	152.7	57.191	44.918	23.758
$\frac{5}{8}$	197.7	155.2	58.141	45.664	23.955
$\frac{11}{16}$	200.9	157.8	59.098	46.415	24.151
$\frac{3}{4}$	204.2	160.3	60.063	47.173	24.347
$\frac{13}{16}$	207.6	163.0	61.035	47.937	24.544
$\frac{7}{8}$	210.8	165.6	62.016	48.707	24.740
$\frac{15}{16}$	214.2	168.2	63.004	49.483	24.936

WEIGHTS AND AREAS OF SQUARE AND ROUND BARS AND CIRCUMFERENCES OF ROUND BARS—(*Continued*).

Thickness or Diameter in Inches.	Weight of □ Bar One Foot Long.	Weight of ○ Bar One Foot Long.	Area of □ Bar in Square Inches.	Area of ○ Bar in Square Inches.	Circumference of ○ Bar in Inches.
8	217.6	171.0	64.000	50.265	25.133
1/16	221.0	173.6	65.004	51.054	25.329
1/8	224.5	176.3	66.016	51.849	25.525
3/16	228.0	179.0	67.035	52.649	25.722
1/4	231.4	181.8	68.063	53.456	25.918
5/16	234.9	184.5	69.098	54.269	26.114
3/8	238.5	187.3	70.141	55.088	26.311
7/16	242.0	190.1	71.191	55.914	26.507
1/2	245.6	193.0	72.250	56.745	26.704
9/16	249.3	195.7	73.316	57.583	26.900
5/8	252.9	198.7	74.391	58.426	27.096
11/16	256.6	201.6	75.473	59.276	27.293
3/4	260.3	204.4	76.563	60.132	27.489
13/16	264.1	207.4	77.660	60.994	27.685
7/8	267.9	210.3	78.766	61.862	27.882
15/16	271.6	213.3	79.879	62.737	28.078
9	275.4	216.3	81.000	63.617	28.274
1/16	279.3	219.3	82.129	64.505	28.471
1/8	283.2	222.4	83.266	65.397	28.667
3/16	287.0	225.4	84.410	66.296	28.863
1/4	290.9	228.5	85.563	67.201	29.060
5/16	294.9	231.5	86.723	68.112	29.256
3/8	298.9	234.7	87.891	69.029	29.452
7/16	302.8	237.9	89.066	69.953	29.649
1/2	306.8	241.0	90.250	70.882	29.845
9/16	310.9	244.2	91.441	71.818	30.041
5/8	315.0	247.4	92.641	72.760	30.238
11/16	319.1	250.6	93.848	73.708	30.434
3/4	323.2	253.9	95.063	74.662	30.631
13/16	327.4	257.1	96.285	75.622	30.827
7/8	331.6	260.4	97.516	76.589	31.023
15/16	335.8	263.7	98.754	77.561	31.022

WEIGHT OF SHEETS OF WROUGHT IRON, STEEL, COPPER, AND BRASS (from HASWELL).

Weights per square foot. Thickness by Birmingham Gauge.

Number of Gauge.	Thickness in Inches.	Iron.	Steel.	Copper.	Brass.
0000	.454	18.22	18.46	20.57	19.43
000	.425	17.05	17.28	19.25	18.19
00	.38	15.25	15.45	17.21	16.26
0	.34	13.64	13.82	15.40	14.55
1	.3	12.04	12.20	13.59	12.84
2	.284	11.40	11.55	12.87	12.16
3	.259	10.39	10.53	11.73	11.09
4	.238	9.55	9.68	10.78	10.19
5	.22	8.83	8.95	9.97	9.42
6	.203	8.15	8.25	9.20	8.69
7	.18	7.22	7.32	8.15	7.70
8	.165	6.62	6.71	7.47	7.06
9	.148	5.94	6.02	6.70	6.33
10	.134	5.38	5.45	6.07	5.74
11	.12	4.82	4.88	5.44	5.14
12	.109	4.37	4.43	4.94	4.67
13	.095	3.81	3.86	4.30	4.07
14	.083	3.33	3.37	3.76	3.55
15	.072	2.89	2.93	3.26	3.08
16	.065	2.61	2.64	2.94	2.78
17	.058	2.33	2.36	2.63	2.48
18	.049	1.97	1.99	2.22	2.10
19	.042	1.69	1.71	1.90	1.80
20	.035	1.40	1.42	1.59	1.50
21	.032	1.28	1.30	1.45	1.37
22	.028	1.12	1.14	1.27	1.20
23	.025	1.00	1.02	1.13	1.07
24	.022	.883	.895	1.00	.942
25	.02	.803	.813	.906	.856
26	.018	.722	.732	.815	.770
27	.016	.642	.651	.725	.685
28	.014	.562	.569	.634	.599
29	.013	.522	.529	.589	.556
30	.012	.482	.488	.544	.514
31	.01	.401	.407	.453	.428
32	.009	.361	.366	.408	.385
33	.008	.321	.325	.362	.342
34	.007	.281	.285	.317	.300
35	.005	.201	.203	.227	.214
Specific gravity....		7.704	7.806	8.698	8.218
Weight cubic foot..		481.75	487.75	543.6	513.6
Weight cubic inch..		.2787	.2823	.3146	.2972

WEIGHT OF SHEETS OF WROUGHT IRON, STEEL, COPPER AND BRASS (from HASWELL).

Weights per sq. ft. Thickness by American (Browne & Sharpe's) Gauge.

Number of Gauge.	Thickness in Inches.	Iron.	Steel.	Copper.	Brass.
0000	.46	18.46	18.70	20.84	19.69
000	.4096	16.44	16.66	18.56	17.53
00	.3648	14.64	14.83	16.53	15.61
0	.3249	13.04	13.21	14.72	13.90
1	.2893	11.61	11.76	13.11	12.38
2	.2576	10.34	10.48	11.67	11.03
3	.2294	9.21	9.33	10.39	9.82
4	.2043	8.20	8.31	9.26	8.74
5	.1819	7.30	7.40	8.24	7.79
6	.1620	6.50	6.59	7.34	6.93
7	.1443	5.79	5.87	6.54	6.18
8	.1285	5.16	5.22	5.82	5.50
9	.1144	4.59	4.65	5.18	4.90
10	.1019	4.09	4.14	4.62	4.36
11	.0907	3.64	3.69	4.11	3.88
12	.0808	3.24	3.29	3.66	3.46
13	.0720	2.89	2.93	3.26	3.08
14	.0641	2.57	2.61	2.90	2.74
15	.0571	2.29	2.32	2.59	2.44
16	.0508	2.04	2.07	2.30	2.18
17	.0453	1.82	1.84	2.05	1.94
18	.0403	1.62	1.64	1.83	1.73
19	.0359	1.44	1.46	1.63	1.54
20	.0320	1.28	1.30	1.45	1.37
21	.0285	1.14	1.16	1.29	1.22
22	.0253	1.02	1.03	1.15	1.08
23	.0226	.906	.918	1.02	.966
24	.0201	.807	.817	.911	.860
25	.0179	.718	.728	.811	.766
26	.0159	.640	.648	.722	.682
27	.0142	.570	.577	.643	.608
28	.0126	.507	.514	.573	.541
29	.0113	.452	.458	.510	.482
30	.0100	.402	.408	.454	.429
31	.0089	.358	.363	.404	.382
32	.0080	.319	.323	.360	.340
33	.0071	.284	.288	.321	.303
34	.0063	.253	.256	.286	.270
35	.0056	.225	.228	.254	.240

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL I BEAMS.

In Tons of 2000 Lbs.

Distance between Supports in Feet.	24″ I.	Add for Every Lb. Increase in Weight.	20″ I.		Add for Every Lb. Increase in Weight.	18″ I.	Add for Every Lb. Increase in Weight.	15″ I.			Add for Every Lb. Increase in Weight.
	80 Lbs.		80 Lbs.	65 Lbs.		55 Lbs.		80 Lbs.	60 Lbs.	42 Lbs.	
12	77.33	.53	65.18	51.98	.44	39.29	.39	47.14	36.09	26.18	.33
13	71.38	.48	60.16	47.98	.40	36.27	.36	43.51	33.31	24.17	.30
14	66.28	.45	55.87	44.56	.37	33.68	.34	40.40	30.93	22.44	.28
15	61.86	.42	52.14	41.59	.35	31.43	.31	37.71	28.87	20.94	.26
16	58.00	.39	48.88	38.99	.33	29.47	.29	35.35	27.07	19.63	.24
17	54.58	.37	46.01	36.69	.31	27.74	.28	33.27	25.47	18.48	.23
18	51.56	.35	43.45	34.66	.29	26.19	.26	31.42	24.06	17.45	.22
19	48.84	.33	41.17	32.83	.28	24.82	.25	29.77	22.79	16.53	.21
20	46.40	.32	39.11	31.19	.26	23.58	.24	28.28	21.65	15.71	.20
21	44.19	.30	37.24	29.70	.25	22.45	.22	26.94	20.62	14.96	.19
22	42.18	.29	35.55	28.35	.24	21.43	.21	25.71	19.68	14.28	.18
23	40.35	.27	34.01	27.12	.23	20.50	.20	24.59	18.83	13.66	.17
24	38.67	.26	32.59	25.99	.22	19.65	.20	23.57	18.04	03.19	.16
25	37.12	.25	31.29	24.95	.21	18.86	.19	22.63	17.32	12.57	.16
26	35.69	.24	30.08	23.99	.20	18.14	.18	21.76	16.66	12.08	.15
27	34.37	.23	28.97	23.10	.19	17.46	.17	20.95	16.04	11.64	.14
28	33.14	.23	27.93	22.28	.19	16.84	.17	20.20	15.47	11.22	.14
29	32.00	.22	26.97	21.51	.18	16.26	.16	19.51	14.93	10.83	.13
30	30.93	.21	26.07	20.79	.17	15.72	.16	18.86	14.43	10.47	.13
31	29.94	.20	25.23	20.12	.17	15.21	.15	18.25	13.97	10.13	.13
32	29.00	.20	24.44	19.49	.16	14.73	.15	17.68	13.53	9.82	.12
33	28.12	.19	23.70	18.90	.16	14.29	.14	17.14	13.12	9.52	.12
34	27.29	.19	23.00	18.35	.15	13.87	.14	16.64	12.74	9.24	.11
35	26.51	.18	22.35	17.82	.15	13.47	.13	16.16	12.37	8.98	.11
36	25.78	.18	21.73	17.33	.15	13.10	.13	15.71	12.03	8.73	.11

Safe loads given include weight of beam. Maximum fibre stress, 16,000 lbs. per square inch.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL I BEAMS.

In Tons of 2000 Lbs.

Distance between Supports in Feet.	12″ I. 40 Lbs.	12″ I. 31.5 Lbs.	Add for Every Lb. Increase in Weight.	10″ I. 25 Lbs.	Add for Every Lb. Increase in Weight.	9″ I. 21 Lbs.	Add for Every Lb. Increase in Weight.	Distance between Supports in Feet.	8″ I. 18 Lbs.	Add for Every Lb. Increase in Weight.
12	19.92	15.99	.26	10.85	.22	8.39	.20	5	15.17	.42
13	18.39	14.76	.24	10.02	.20	7.74	.18	6	12.64	.35
14	17.08	13.70	.23	9.30	.19	7.19	.17	7	10.84	.30
15	15.94	12.79	.21	8.68	.17	6.71	.16	8	9.48	.26
16	14.94	11.99	.20	8.14	.16	6.29	.15	9	8.43	.23
17	14.06	11.29	.19	7.66	.15	5.92	.14	10	7.59	.21
18	13.28	10.66	.18	7.24	.14	5.59	.13	11	6.90	.19
19	12.58	10.10	.17	6.86	.14	5.30	.12	12	6.32	.18
20	11.95	9.59	.16	6.51	.13	5.03	.12	13	5.83	.16
21	11.38	9.14	.15	6.20	.12	4.79	.11	14	5.42	.15
22	10.87	8.72	.14	5.92	.12	4.58	.11	15	5.06	.14
23	10.39	8.34	.14	5.66	.11	4.38	.10	16	4.74	.13
24	9.96	7.99	.13	5.43	.11	4.19	.10	17	4.46	.12
25	9.56	7.67	.13	5.21	.10	4.03	.09	18	4.21	.12
26	9.19	7.38	.12	5.01	.10	3.87	.09	19	3.99	.11
27	8.85	7.11	.12	4.82	.10	3.73	.09	20	3.79	.11
28	8.54	6.85	.11	4.65	.09	3.59	.08	21	3.61	.10
29	8.24	6.62	.11	4.49	.09	3.47	.08	....	....	....
30	7.97	6.40	.11	4.34	.09	3.36	.08	....	....	....

Safe loads given include weight of beam. Maximum fibre stress, 16,000 lbs. per square inch.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL I BEAMS.

In Tons of 2000 Lbs.

Distance between Supports in Feet.	7″ I. 15 lbs.	Add for Every Lb. Increase in Weight.	6″ I. 12.25 lbs.	Add for Every Lb. Increase in Weight.	5″ I. 9.75 lbs.	Add for Every Lb. Increase in Weight.	4″ I. 7.5 lbs.	Add for Every Lb. Increase in Weight.	3″ I. 5.5 lbs.	Add for Every Lb. Increase in Weight.
5	11.04	.36	7.75	.31	5.16	.26	3.18	.21	1.76	.16
6	9.20	.30	6.46	.26	4.30	.22	2.65	.18	1.47	.13
7	7.89	.26	5.54	.22	3.69	.19	2.27	.15	1.26	.11
8	6.90	.23	4.84	.19	3.23	.16	1.99	.13	1.10	.10
9	6.13	.20	4.31	.17	2.87	.14	1.77	.12	0.98	.09
10	5.52	.18	3.88	.16	2.58	.13	1.59	.11	0.88	.08
11	5.02	.16	3.52	.14	2.35	.12	1.45	.10	0.80	.07
12	4.60	.15	3.23	.13	2.15	.11	1.33	.09	0.73	.07
13	4.25	.14	2.98	.12	1.98	.10	1.22	.08	0.68	.06
14	3.94	.13	2.77	.11	1.84	.09	1.14	.08	0.63	.06
15	3.68	.12	2.58	.10	1.72	.09	1.06	.07	0.59	.05
16	3.45	.11	2.42	.10	1.61	.08	0.99	.07	0.55	.05
17	3.25	.11	2.28	.09	1.52	.08	0.94	.06	0.52	.05
18	3.07	.10	2.15	.09	1.43	.07	0.88	.06	0.49	.04
19	2.91	.09	2.04	.08	1.36	.07	0.84	.06	0.46	.04
20	2.76	.09	1.94	.08	1.29	.07	0.80	.05	0.44	.04
21	2.63	.09	1.85	.07	1.23	.06	0.76	.05	0.42	.04

Safe loads given include weight of beam. Maximum fibre stress, 16,000 lbs. per square inch.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL CHANNELS.

In Tons of 2000 Lbs.

Distance between Supports in Feet.	15″ ⊏ 33 lbs.	Add for Every Lb. Increase in Weight.	12″ ⊏ 20.5 lbs.	Add for Every Lb. Increase in Weight.	10″ ⊏ 15 lbs.	Add for Every Lb. Increase in Weight.	9″ ⊏ 13.25 lbs.	Add for Every Lb. Increase in Weight.
10	22.23	.39	11.39	.32	7.14	.26	5.61	.24
11	20.20	.35	10.35	.29	6.49	.24	5.10	.21
12	18.52	.33	9.49	.26	5.95	.22	4.68	.20
13	17.10	.30	8.76	.24	5.49	.20	4.32	.18
14	15.87	.28	8.14	.23	5.10	.19	4.01	.17
15	14.82	.26	7.59	.21	4.76	.17	3.74	.16
16	13.89	.24	7.12	.20	4.46	.16	3.51	.15
17	13.07	.23	6.70	.18	4.20	.15	3.30	.14
18	12.35	.22	6.33	.18	3.96	.14	3.12	.13
19	11.70	.21	5.99	.17	3.76	.14	2.95	.12
20	11.11	.20	5.70	.16	3.57	.13	2.81	.12
21	10.58	.19	5.42	.15	3.40	.12	2.67	.11
22	10.10	.18	5.18	.14	3.24	.12	2.55	.11
23	9.66	.17	4.95	.14	3.10	.11	2.44	.10
24	9.26	.16	4.75	.13	2.97	.11	2.34	.10
25	8.89	.16	4.56	.13	2.85	.10	2.24	.09
26	8.55	.15	4.38	.12	2.74	.10	2.16	.09
27	8.23	.14	4.22	.12	2.64	.10	2.08	.09
28	7.94	.14	4.07	.11	2.55	.09	2.00	.08
29	7.66	.13	3.93	.11	2.46	.09	1.93	.08
30	7.41	.13	3.80	.11	2.38	.09	1.87	.08

Safe loads given include weight of channel. Maximum fibre stress, 16,000 lbs. per square inch.

SAFE LOADS UNIFORMLY DISTRIBUTED FOR STANDARD AND SPECIAL CHANNELS.

In Tons of 2000 Lbs.

Distance between Supports in Feet.	8″ [11.25 Lbs.	Add for Every Lb. Increase in Weight.	7″ [9.75 Lbs.	Add for Every Lb. Increase in Weight.	6″ [8 Lbs.	Add for Every Lb. Increase in Weight.	5″ [6.5 Lbs.	Add for Every Lb. Increase in Weight.	4″ [5.25 Lbs.	Add for Every Lb. Increase in Weight.	3″ [4 Lbs.	Add for Every Lb. Increase in Weight.
5	8.61	.42	6.68	.36	4.62	.31	3.16	.26	2.02	.21	1.16	.16
6	7.18	.35	5.57	.30	3.85	.26	2.63	.22	1.68	.18	.97	.13
7	6.15	.30	4.77	.26	3.30	.22	2.26	.19	1.44	.15	.83	.11
8	5.38	.26	4.18	.23	2.89	.19	1.98	.16	1.26	.13	.73	.10
9	4.78	.23	3.71	.20	2.57	.17	1.76	.14	1.12	.12	.64	.09
10	4.31	.21	3.34	.18	2.31	.16	1.58	.13	1.01	.11	.58	.08
11	3.91	.19	3.04	.16	2.10	.14	1.44	.12	.92	.10	.53	.07
12	3.59	.18	2.78	.15	1.93	.13	1.32	.11	.84	.09	.48	.07
13	3.31	.16	2.57	.14	1.78	.12	1.22	.10	.78	.08	.45	.06
14	3.08	.15	2.39	.13	1.65	.11	1.13	.09	.72	.08	.41	.06
15	2.87	.14	2.23	.12	1.54	.10	1.05	.09	.67	.07	.39	.05
16	2.69	.13	2.09	.11	1.44	.10	.99	.08	.63	.07	.36	.05
17	2.53	.12	1.96	.11	1.36	.09	.93	.08	.59	.06	.34	.05
18	2.39	.11	1.86	.10	1.28	.09	.88	.07	.56	.06	.32	.04
19	2.27	.11	1.76	.09	1.22	.08	.83	.07	.53	.06	.31	.04
20	2.15	.11	1.67	.09	1.16	.08	.79	.07	.51	.05	.29	.04
21	2.05	.10	1.59	.09	1.10	.07	.75	.06	.48	.05	.28	.04
22	1.96	.10	1.52	.08	1.05	.07	.72	.06	.46	.05	.26	.04
23	1.87	.09	1.45	.08	1.00	.07	.69	.06	.44	.05	.25	.03
24	1.79	.09	1.39	.08	.96	.06	.66	.05	.42	.04	.24	.03
25	1.72	.08	1.34	.07	.92	.06	.63	.05	.40	.04	.23	.03

Safe loads given include weight of channel. Maximum fibre stress, 16,000 lbs. per square inch.

PROPERTIES OF

1 Section Index.	2 Depth of Beam, Inches.	3 Weight per Foot, Pounds.	4 Area of Section, Square Inches.	5 Thickness of Web, Inches.	6 Width of Flange, Inches.	7 Mom. of Inertia, Neutral Axis Perpendicular to Web at Centre. I	8 Mom. of Inertia, Neutral Axis Coincident with Centre Line of Web. I'	9 Radius of Gyration, Neutral Axis Perpendicular to Web at Centre. r
B 1	24	100.00	29.41	0.754	7.254	2380.3	48.56	9.00
		95.00	27.94	0.692	7.192	2309.6	47.10	9.09
		90.00	26.47	0.631	7.131	2239.1	45.70	9.20
		85.00	25.00	0.570	7.070	2168.6	44.35	9.31
		80.00	**23.32**	**0.500**	**7.000**	**2087.9**	**42.86**	9.46
B 2	20	100.00	29.41	0.884	7.284	1655.8	52.65	7.50
		95.00	27.94	0.810	7.210	1606.8	50.78	7.58
		90.00	26.47	0.737	7.137	1557.8	48.98	7.67
		85.00	25.00	0.663	7.063	1508.7	47.25	7.77
		80.00	**23.73**	**0.600**	**7.000**	**1466.5**	**45.81**	**7.86**
B 3	20	75.00	22.06	0.649	6.399	1268.9	30.25	7.58
		70.00	20.59	0.575	6.325	1219.9	29.04	7.70
		65.00	**19.08**	**0.500**	**6.250**	**1169.6**	**27.86**	**7.83**
B80	18	70.00	20.59	0.719	6.259	921.3	24.62	6.69
		65.00	19.12	0.637	6.177	881.5	23.47	6.79
		60.00	17.65	0.555	6.095	841.8	22.38	6.91
		55.00	**15.93**	**0.460**	**6.000**	**795.6**	**21.19**	**7.07**
B 4	15	100.00	29.41	1.184	6.774	900.5	50.98	5.53
		95.00	27.94	1.085	6.675	872.9	48.37	5.59
		90.00	26.47	0.987	6.577	845.4	45.91	5.65
		85.00	25.00	0.889	6.479	817.8	43.57	5.72
		80.00	**23.81**	**0.810**	**6.400**	**795.5**	**41.76**	**5.78**
B 5	15	75.00	22.06	0.882	6.292	691.2	30.68	5.60
		70.00	20.59	0.784	6.194	663.6	29.00	5.68
		65.00	19.12	0.686	6.096	636.0	27.42	5.77
		60.00	**17.67**	**0.590**	**6.000**	**609.0**	**25.96**	**5.87**
B 7	15	55.00	16.18	0.656	5.746	511.0	17.06	5.62
		50.00	14.71	0.558	5.648	483.4	16.04	5.73
		45.00	13.24	0.460	5.550	455.8	15.00	5.87
		42.00	**12.48**	**0.410**	**5.500**	**441.7**	**14.62**	**5.95**
B 8	12	55.00	16.18	0.822	5.612	321.0	17.46	4.45
		50.00	14.71	0.699	5.489	303.3	16.12	4.54
		45.00	13.24	0.576	5.366	285.7	14.89	4.65
		40.00	**11.84**	**0.460**	**5.250**	**268.9**	**13.81**	**4.77**
B 9	12	35.00	10.29	0.436	5.086	228.3	10.07	4.71
		31.50	**9.26**	**0.350**	**5.000**	**215.8**	**9.50**	**4.83**
B10	10	40.00	11.76	0.749	5.099	158.7	9.50	3.67
		35.00	10.29	0.602	4.952	146.4	8.52	3.77
		30.00	8.82	0.455	4.805	134.2	7.65	3.90
		25.00	**7.37**	**0.310**	**4.660**	**122.1**	**6.89**	**4.07**

L = safe load in pounds uniformly distributed; l = span in feet.
M' = moment of forces in foot-pounds; C and C' = coefficients given on opposite page.

Weights in heavy print are standard, others are special.

I BEAMS.

10 Radius of Gyration, Neutral Axis Coincident with Centre Line of Web. r'	11 Section Modulus, Neutral Axis Perpendicular to Web at Centre. S	12 Coefficient of Stren'h for Fibre Stress of 16,000 Lbs. per Sq. In. Used for Buildings. C	13 Coefficient of Stren'h for Fibre Stress of 12,500 Lbs. per Sq. In. Used for Bridges. C'	14 Distance Centre to Centre Required to make Radii of Gyration Equal. D	15 Section Index.
1.28	198.4	2115800	1653000	17.82	
1.30	192.5	2052900	1603900	17.99	
1.31	186.6	1990300	1554900	18.21	B 1
1.33	180.7	1927600	1505900	18.43	
1.36	**174.0**	**1855900**	**1449900**	**18.72**	
1.34	165.6	1766100	1379800	14.76	
1.35	160.7	1713900	1339000	14.92	
1.36	155.8	1661600	1298100	15.10	B 2
1.37	150.9	1609300	1257200	15.30	
1.39	**146.7**	**1564300**	**1222100**	**15.47**	
1.17	126.9	1353500	1057400	14.98	
1.19	122.0	1301200	1016600	15.21	B 3
1.21	**117.0**	**1247600**	**974700**	**15.47**	
1.09	102.4	1091900	853000	13.20	
1.11	97.9	1044800	816200	13.40	
1.13	93.5	997700	779500	13.63	B80
1.15	**88.4**	**943000**	**736700**	**13.95**	
1.31	120.1	1280700	1000600	10.75	
1.32	116.4	1241500	969900	10.86	
1.32	112.7	1202300	939300	10.99	B 4
1.32	109.0	1163000	908600	11.13	
1.32	**106.1**	**1131300**	**883900**	**11.25**	
1.18	92.2	983000	768000	10.95	
1.19	88.5	943800	737400	11.11	
1.20	84.8	904600	706700	11.29	B 5
1.21	**81.2**	**866100**	**676600**	**11.49**	
1.02	68.1	726800	567800	11.05	
1.04	64.5	687500	537100	11.27	
1.07	60.8	648200	506400	11.54	B 7
1.08	**58.9**	**628300**	**490800**	**11.70**	
1.04	53.5	570600	445800	8.65	
1.05	50.6	539200	421300	8.83	
1.06	47.6	507900	396800	9.06	B 8
1.08	**44.8**	**478100**	**373500**	**9.29**	
0.99	38.0	405800	317000	9.21	B 9
1.01	**36.0**	**383700**	**299700**	**9.45**	
0.90	31.7	338500	264500	7.12	
0.91	29.3	312400	244100	7.32	
0.93	26.8	286300	223600	7.57	B11
0.97	**24.4**	**260500**	**203500**	**7.91**	

$$L=\frac{C \text{ or } C'}{l}; \quad M'=\frac{C \text{ or } C'}{8}; \quad C \text{ or } C'=Ll=8M'=\frac{8fS}{12}.$$

PROPERTIES OF

1 Section Index.	2 Depth of Beam, Inches.	3 Weight per Foot, Pounds.	4 Area of Section, Square Inches.	5 Thickness of Web, Inches.	6 Width of Flange, Inches.	7 Mom. of Inertia, Neutral Axis Perpendicular to Web at Centre. I	8 Mom. of Inertia, Neutral Axis Coincident with Centre Line of Web. I'	9 Radius of Gyration, Neutral Axis Perpendicular to Web at Centre. r
B13	9	35.00	10.29	0.732	4.772	111.8	7.31	3.29
		30.00	8.82	0.569	4.609	101.9	6.42	3.40
		25.00	7.35	0.406	4.446	91.9	5.65	3.54
		21.00	**6.31**	**0.290**	**4.330**	**84.9**	**5.16**	**3.67**
B15	8	25.50	7.50	0.541	4.271	68.4	4.75	3.02
		23.00	6.76	0.449	4.179	64.5	4.39	3.09
		20.50	6.03	0.357	4.087	60.6	4.07	3.17
		18.00	**5.33**	**0.270**	**4.000**	**56.9**	**3.78**	**3.27**
B17	7	20.00	5.88	0.458	3.868	42.2	3.24	2.68
		17.50	5.15	0.353	3.763	39.2	2.94	2.76
		15.00	**4.42**	**0.250**	**3.660**	**36.2**	**2.67**	**2.86**
B19	6	17.25	5.07	0.475	3.575	26.2	2.36	2.27
		14.75	4.34	0.352	3.452	24.0	2.09	2.35
		12.25	**3.61**	**0.230**	**3.330**	**21.8**	**1.85**	**2.46**
B21	5	14.75	4.34	0.504	3.294	15.2	1.70	1.87
		12.25	3.60	0.357	3.147	13.6	1.45	1.94
		9.75	**2.87**	**0.210**	**3.000**	**12.1**	**1.23**	**2.05**
B23	4	10.50	3.09	0.410	2.880	7.1	1.01	1.52
		9.50	2.79	0.337	2.807	6.7	0.93	1.55
		8.50	2.50	0.263	2.733	6.4	0.85	1.59
		7.50	**2.21**	**0.190**	**2.660**	**6.0**	**0.77**	**1.64**
B77	3	7.50	2.21	0.361	2.521	2.9	0.60	1.15
		6.50	1.91	0.263	2.423	2.7	0.53	1.19
		5.50	**1.63**	**0.170**	**2.330**	**2.5**	**0.46**	**1.23**

Weights in heavy print are standard, others are special.

I BEAMS—(*Continued*).

10 Radius of Gyration, Neutral Axis Coincident with Centre Line of Web. r'	11 Section Modulus, Neutral Axis Perpendicular to Web at Centre. S	12 Coefficient of Stren'h for Fibre Stress of 16,000 Lbs. per Sq. In. Used for Buildings. C	13 Coefficient of Stren'h for Fibre Stress of 12,500 Lbs. per Sq. In. Used for Bridges. C'	14 Distance Centre to Centre Required to make Radii of Gyration Equal. 	15 Section Index.
0.84	24.8	265000	207000	6.36	
0.85	22.6	241500	188700	7.58	B13
0.88	20.4	217900	170300	6.86	
0.90	**18.9**	**201300**	**157300**	**7.12**	
0.80	17.1	182500	142600	5.82	
0.81	16.1	172000	134400	5.96	B15
0.82	15.1	161600	126200	6.12	
0.84	**14.2**	**151700**	**118500**	**6.32**	
0.74	12.1	128600	100400	5.15	
0.76	11.2	119400	93300	5.31	B17
0.78	**10.4**	**110400**	**86300**	**5.50**	
0.68	8.7	93100	72800	4.33	
0.69	8.0	85300	66600	4.49	B19
0.72	**7.3**	**77500**	**60500**	**4.70**	
0.63	6.1	64600	50500	....	
0.63	5.4	58100	45400	....	B21
0.65	**4.8**	**51600**	**40300**	....	
0.57	3.6	38100	29800	....	
0.58	3.4	36000	28100	....	
0.58	3.2	33900	26500	....	B23
0.59	**3.0**	**31800**	**24900**	....	
0.52	1.9	20700	16200	....	
0.52	1.8	19100	15000	....	B77
0.53	**1.7**	**17600**	**13800**	....	

PROPERTIES OF

1 Section Index.	2 Depth of Channel, Inches.	3 Weight per Foot, Pounds.	4 Area of Section, Square Inches.	5 Thickness of Web, Inches.	6 Width of Flange, Inches.	7 Mom. of Inertia, Neutral Axis Perpendicular to Web at Centre. I	8 Mom. of Inertia, Neutral Axis Parallel with Centre Line of Web. I'	9 Radius of Gyration, Neutral Axis Perpendicular to Web at Centre. r
C 1	15	55.00	16.18	0.818	3.818	430.2	12.19	5.16
		50.00	14.71	0.720	3.720	402.7	11.22	5.23
		45.00	13.24	0.622	3.622	375.1	10.29	5.32
		40.00	11.76	0.524	3.524	347.5	9.39	5.43
		35.00	10.29	0.426	3.426	320.0	8.48	5.58
		33.00	**9.90**	**0.400**	**3.400**	**312.6**	**8.23**	**5.62**
C 2	12	40.00	11.76	0.758	3.418	197.0	6.63	4.09
		35.00	10.29	0.636	3.296	179.3	5.90	4.17
		30.00	8.82	0.513	3.173	161.7	5.21	4.28
		25.00	7.35	0.390	3.050	144.0	4.53	4.43
		20.50	**6.03**	**0.280**	**2.940**	**128.1**	**3.91**	**4.61**
C 3	10	35.00	10.29	0.823	3.183	115.5	4.66	3.35
		30.00	8.82	0.676	3.036	103.2	3.90	3.42
		25.00	7.35	0.529	2.889	91.0	3.40	3.52
		20.00	5.88	0.382	2.742	78.7	2.85	3.66
		15.00	**4.46**	**0.240**	**2.600**	**66.9**	**2.30**	**3.87**
C 4	9	25.00	7.35	0.615	2.815	70.7	2.98	3.10
		20.00	5.88	0.452	2.652	60.8	2.45	3.21
		15.00	4.41	0.288	2.488	50.9	1.95	3.40
		13.25	**3.89**	**0.230**	**2.430**	**47.3**	**1.77**	**3.49**
C 5	8	21.25	6.25	0.582	2.622	47.8	2.25	2.77
		18.75	5.51	0.490	2.530	43.8	2.01	2.82
		16.25	4.78	0.399	2.439	39.9	1.78	2.89
		13.75	4.04	0.307	2.347	36.0	1.55	2.98
		11.25	**3.35**	**0.220**	**2.260**	**32.3**	**1.33**	**3.11**
C 6	7	19.75	5.81	0.633	2.513	33.2	1.85	2.39
		17.25	5.07	0.528	2.408	30.2	1.62	2.44
		14.75	4.34	0.423	2.303	27.2	1.40	2.50
		12.25	3.60	0.318	2.198	24.2	1.19	2.59
		9.75	**2.85**	**0.210**	**2.090**	**21.1**	**0.98**	**2.72**
C 7	6	15.50	4.56	0.563	2.283	19.5	1.28	2.07
		13.00	3.82	0.440	2.160	17.3	1.07	2.13
		10.50	3.09	0.318	2.038	15.1	0.88	2.21
		8.00	**2.38**	**0.200**	**1.920**	**13.0**	**0.70**	**2.34**
C 8	5	11.50	3.38	0.477	2.037	10.4	0.82	1.75
		9.00	2.65	0.330	1.890	8.9	0.64	1.83
		6.50	**1.95**	**0.190**	**1.750**	**7.4**	**0.48**	**1.95**
C 9	4	7.25	2.13	0.325	1.725	4.6	0.44	1.46
		6.25	1.84	0.252	1.652	4.2	0.38	1.51
		5.25	**1.55**	**0.180**	**1.580**	**3.8**	**0.32**	**1.56**
C72	3	6.00	1.76	0.362	1.602	2.1	0.31	1.08
		5.00	1.47	0.264	1.504	1.8	0.25	1.12
		4.00	**1.19**	**0.170**	**1.410**	**1.6**	**0.20**	**1 17**

L = safe load in pounds uniformly distributed; l = span in feet.
M' = moment of forces in foot-pounds; C and C' = coefficients given on opposite page.

Weights in heavy print are standard, others are special.

CHANNELS.

10 Radius of Gyration, Neutral Axis Parallel with Centre Line of Web. r'	11 Section Modulus, Neutral Axis Perpendicular to Web at Centre. S	12 Coefficient of Stren'h for Fibre Stress of 16,000 Lbs. per Sq. In. Used for Buildings. C	13 Coefficient of Stren'h for Fibre Stress of 12,500 Lbs. per Sq In. Used for Bridges. C'	14 Distance Required to make Radii of Gyration Equal.	15 Distance of Centre of Gravity from Outside of Web. x	16 Section Index.
.868	57.4	611900	478000	8.53	0.823	
.873	53.7	572700	447400	8.71	0.803	
.882	50.0	533500	416800	8.92	0.788	
.893	46.3	494200	386100	9.15	0.783	C 1
.908	42.7	455000	355500	9.43	0.789	
.912	**41.7**	**444500**	**347300**	**9.50**	**0.794**	
.751	32.8	350200	273600	6.60	0.722	
.757	29.9	318800	249100	6.81	0.694	
.768	26.9	287400	224500	7.07	0.677	C 2
.785	24.0	256100	200000	7.36	0.678	
.805	**21.4**	**227800**	**178000**	**7.67**	**0.704**	
.672	23.1	246400	192500	5.17	0.695	
.672	20.6	220300	172100	5.40	0.651	
.680	18.2	194100	151700	5.67	0.620	C 3
.696	15.7	168000	131200	5.97	0.609	
.718	**13.4**	**142700**	**111500**	**6.33**	**0.639**	
.637	15.7	167600	130900	4.84	0.615	
.646	13.5	144100	112600	5.12	0.585	
.665	11.3	120500	94200	5.49	0.590	C 4
.674	**10.5**	**112200**	**87600**	**5.63**	**0.607**	
.600	11.9	127400	99500	4.23	0.587	
.603	11.0	116900	91300	4.38	0.567	
.610	10.0	106400	83200	4.54	0.556	C 5
.619	9.0	96000	75000	4.72	0.557	
.630	**8.1**	**86100**	**67300**	**4.94**	**0.576**	
.565	9.5	101100	79000	3.48	0.583	
.564	8.6	92000	71800	3.64	0.555	
.568	7.8	82800	64700	3.80	0.535	C 6
.575	6.9	73700	57500	3.99	0.528	
.586	**6.0**	**66800**	**52200**	**4.22**	**0.546**	
.529	6.5	69500	54300	2.91	0.546	
.529	5.8	61600	48100	3.09	0.517	
.534	5.0	53800	42000	3.28	0.503	C 7
.542	**4.3**	**46200**	**36100**	**3.52**	**0.517**	
.493	4.2	44400	34700	2.34	0.508	
.493	3.5	37900	29600	2.56	0.481	C 8
.498	**3.0**	**31600**	**24700**	**2.79**	**0.489**	
.455	2.3	24400	19000	1.85	0.463	
.454	2.1	22300	17400	1.96	0.458	C 9
.453	**1.9**	**20200**	**15800**	**2.06**	**0.464**	
.421	1.4	14700	11500	1.07	0.459	
.415	1.2	13100	10300	1.19	0.443	C72
.409	**1.1**	**11600**	**9100**	**1.31**	**0.443**	

$$L=\frac{C \text{ or } C'}{l};\quad M'=\frac{C \text{ or } C'}{8};\quad C \text{ or } C'=Ll=8M'=\frac{8fS}{12}.$$

The sectional index numbers in the previous tables refer to sections in the Carnegie Steel Co.'s Handbook.

EXPLANATION OF TABLES ON THE PROPERTIES OF STANDARD AND SPECIAL I BEAMS AND CHANNELS.

The tables on I beams and channels are calculated for all weights to which each pattern is rolled.

Columns 12 and 13 in the tables for I beams and channels give coefficients by the help of which the safe, uniformly distributed load may be readily and quickly determined. To do this, it is only necessary to divide the coefficient given by the span or distance between supports in feet.

If a section is to be selected (as will usually be the case) intended to carry a certain load for a length of span already determined on, it will only be necessary to ascertain the coefficient which this load and span will require and refer to the table for a section having a coefficient of this value. The coefficient is obtained by multiplying the load in pounds uniformly distributed by the span length in feet.

In case the load is not uniformly distributed, but is concentrated at the middle of the span, multiply the load by 2 and then consider it as uniformly distributed. The deflection will be $\frac{8}{10}$ of the deflection for the latter load.

For other cases of loading, obtain the bending moment in foot-pounds (the most common cases are given on page 478); this multiplied by 8 will give the coefficient required.

If the loads are quiescent, the coefficients for fibre stress of 16,000 pounds per square inch for steel may be used; but if moving loads are to be provided for, the coefficient for 12,500 pounds should be taken. Inasmuch as the effects of impact may be very considerable (the stresses produced in an unyielding, inelastic material by a load suddenly applied being double those produced by the same load in a quiescent state), it will sometimes be advisable to use still smaller fibre stresses than those given in the tables. In such cases the coefficients can readily be determined by proportion. Thus, for a fibre stress of 8000 pounds per square inch, the coefficient will equal the coefficient for 16,000 pounds fibre stress divided by 2.

The section moduli are used to determine the fibre stress per square inch in a beam or other shape, subjected to bending or transverse stresses, by simply dividing the same into the bending moment expressed in inch-pounds.

Column 14 in the table of the "Properties of Beams" gives the distance c. t. c. of beams making the radii of gyration equal for both axes.

The length of a beam used as a strut should not exceed 125 times its least radius of gyration.

Column 14 in the table of the "Properties of Standard Channels" gives the distance which the channels should be placed back to back to make the radii of gyration equal for both axes. Column 15 in the same table can be used to obtain the radius of gyration for struts consisting of two channels when the distance back to back varies from that given in the table.

These tables have all been prepared with great care. No approximations have entered into any of the calculations, so that the figures given may be relied upon as accurate.

Examples.—I. What section of I beam will be required to carry 40,000 lbs. uniformly distributed, including its own weight, over a span of 16 ft. between supports, allowing a fibre stress of 16,000 lbs. per square inch?

Answer.—The coefficient (C) required $= 40{,}000 \times 16 = 640{,}000$.

In table of Properties of I Beams, page 469, look in column 12 for the nearest number corresponding to 640,000, which is 648,200. Therefore the beam to be used is 15 in. 45 lbs.

The tables on pages 463 to 465 for I beams give the loads which a beam will carry safely (distributed uniformly over its length) for the distances between supports indicated. These loads include the weight of the beam, which must be deducted in order to arrive at the *net load* which the beam will carry. On pages 466 to 467 will also be found the safe loads for channels

For beams of heavier sections than those calculated in the tables, a separate column of corrections is given for each size, stating the proper increase of safe load for every additional pound in the weight per foot of beam. The values given are based on a maximum fibre stress of 16,000 pounds per square inch.

GENERAL FORMULÆ ON THE FLEXURE OF BEAMS OF ANY CROSS-SECTION.

Let A = area of section in square inches,
l = length of span in inches,
W = load uniformly distributed in pounds,
M = bending moment in inch-pounds,
h = height of cross-section, out to out, in inches,
n = distance of centre of gravity of section, from top or from bottom, in inches,
f = stress per square inch in extreme fibres of beam, either top or bottom, in pounds, according as n relates to distance from top or from bottom of section,
D = maximum deflection in inches,
I = moment of inertia of section neutral axis through centre of gravity,
I'' = moment of inertia of section neutral axis parallel to above, but not through centre of gravity,
d = distance between these neutral axes,
S = section modulus,
r = radius of gyration in inches,
E = modulus of elasticity for steel 29,000,000;

then: $S = \frac{I}{n}$, $\quad r = \sqrt{\frac{I}{A}}$,

$$M = \frac{fI}{n} = fS,$$

$$f = \frac{Mn}{I} = \frac{M}{S},$$

$$W = \frac{8fI}{ln} = \frac{8f}{l}S,$$

$$f = \frac{Wln}{8I} = \frac{Wl}{8S},$$

$$I'' = I + Ad^2,$$

$D = \frac{5Wl^3}{384EI}$ for beam supported at both ends and uniformly loaded,

$D = \frac{Pl^3}{48EI}$ for beam supported at both ends and loaded with a single load P at middle,

$D = \frac{Wl^3}{8EI}$ for beam fixed at one end and unsupported at the other and uniformly loaded,

$D = \frac{Pl^3}{3EI}$ for beam fixed at one end and unsupported at other and loaded with a single load P at the latter end.

SPECIAL CASES OF LOADING.—I. Beam loaded by a single load P at a point distant b feet from the left hand and a feet from the right-hand support.

l = length of beam between supports $= a + b$.

Pressure or reaction at left-hand support $= P\frac{a}{l}$ and at right-hand support $= P\frac{b}{l}$.

Maximum bending moment neglecting dead weight of beam occurs at point of application of the load and $= \frac{Pab}{l}$.

P = load given in tables pages 463 to $467 \times \frac{l^2}{8ab}$.

When $a = b = \frac{1}{2}l$:

Reaction $= \frac{P}{2}$; *maximum bending moment* $= \frac{Pl}{4}$ and P = load given in tables $\times \frac{1}{2}$.

II. Beam fixed at one end and unsupported at the other, l representing the length of beam from end to support.

If loaded by a uniformly distributed load W:

Maximum bending moment occurs at support and $= \frac{Wl}{2}$.

W = load given in tables pages 463 to $467 \times \frac{1}{4}$.

If loaded with a single load P at its extremity:

Maximum bending moment occurs at support and $= Pl$.

P = load given in tables $\times \frac{1}{8}$.

When beams have no lateral support the safe load is given in the following table:

BEAMS WITHOUT LATERAL SUPPORT.

Length of Beam.	Proportion of Tabular Load Forming Greatest Safe Load.
20 times flange width	Whole tabular load
30 " " "	9/10 " "
40 " " "	8/10 " "
50 " " "	7/10 " "
60 " " "	6/10 " "
70 " " "	5/10 " "

BENDING MOMENTS AND DEFLECTIONS OF BEAMS UNDER VARIOUS SYSTEMS OF LOADING.

W = total load.
l = length of beam.

I = moment of inertia.
E = modulus of elasticity.

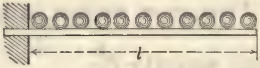
(1) Beam fixed at one end and loaded at the other.

Safe load = $\frac{1}{8}$ that given in tables.
Maximum bending moment at point of support = Wl.

Maximum shear at point of support = W.

Deflection = $\frac{Wl^3}{3EI}$.

(2) Beam fixed at one end and uniformly loaded.

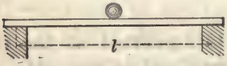


Safe load = $\frac{1}{4}$ that given in tables.
Maximum bending moment at point of support = $\frac{Wl}{2}$.

Maximum shear at point of support = W.

Deflection = $\frac{Wl^3}{8EI}$.

(3) Beam supported at both ends, single load in the middle.

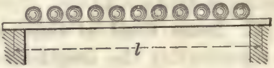


Safe load = $\frac{1}{2}$ that given in tables.
Maximum bending moment at middle of beam = $\frac{Wl}{4}$.

Maximum shear at points of support = $\frac{1}{2}W$.

Deflection = $\frac{Wl^3}{48EI}$.

(4) Beam supported at both ends and uniformly loaded.

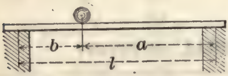


Safe load = that given in tables.
Maximum bending moment at middle of beam = $\frac{Wl}{8}$.

Maximum shear at points of support = $\frac{1}{2}W$.

Deflection = $\frac{Wl^3}{76.8EI}$.

(5) Beam supported at both ends, single unsymmetrical load.



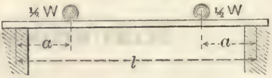
Safe load = that given in tables $\times \frac{l^2}{8ab}$.

Maximum bending moment under load = $\frac{Wab}{l}$.

Maximum shears: at support near $a = \frac{Wb}{l}$; at other support = $\frac{Wa}{l}$.

Max. deflec. = $\frac{Wab(2l-a)}{9EIl}\sqrt{\frac{1}{3}a(2l-a)}$.

(6) Beam supported at both ends two symmetrical loads.



Safe load = that given in tables $\times \frac{l}{4a}$.

Maximum bending moment between loads = $\frac{1}{2}Wa$.

Maximum shear between load and nearer support = $\frac{1}{2}W$.

Max. deflection = $\frac{Wa}{48EI}(3l^2-4a^2)$.

TROUGH-PLATE FLOORING.—The trough and corrugated plate sections shown below are used for floors of bridges and fireproof buildings, as shown in Fig. 243.

The following tables give weights per lineal foot of each rolled section and per square foot of floor surface for thicknesses varying by $\frac{1}{16}$ inch; also the section modulus for 1 foot in width and the safe loads per square foot for spans of different lengths, using fibre stresses of 12,000 and 10,000 pounds.

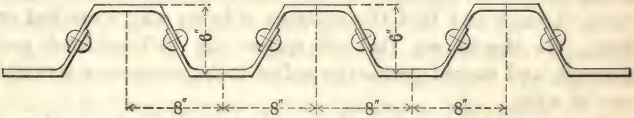


FIG. 243.

PROPERTIES OF TROUGH SECTION.

Section index	M 10	M 11	M 12	M 13	M 14
Thickness of base	$\frac{1}{2}$	$\frac{9}{16}$	$\frac{5}{8}$	$\frac{11}{16}$	$\frac{3}{4}$
Weight per lineal foot	16.3	18.0	19.7	21.4	23.2
Weight per square foot	25.00	28.15	31.31	34.48	37.74
Section modulus for 1 ft. in width	11.56	13.06	14.57	16.12	17.67

SAFE LOADS IN POUNDS PER SQUARE FOOT OF FLOOR FOR SPANS OF DIFFERENT LENGTHS.

Span in Feet.	M 10		M 11		M 12		M 13		M 14	
	12,000 Lbs.	10,000 Lbs.	12,000 Lbs.	10,000 Lbs.	12,000 Lbs.	10,000 Lbs.	12,000 Lbs.	10,000 Lbs.	12,000 Lbs.	10,000 Lbs.
5	3699	3083	4179	3483	4662	3885	5158	4298	5654	4712
6	2569	2141	2902	2418	3238	2698	3582	2985	3927	3272
7	1887	1573	2132	1777	2379	1983	2632	2193	2885	2404
8	1445	1204	1633	1361	1821	1517	2015	1679	2209	1841
9	1142	952	1290	1075	1439	1199	1592	1327	1745	1454
10	925	771	1045	871	1166	972	1290	1075	1414	1178
11	764	637	864	720	963	803	1066	888	1168	973
12	642	535	726	605	809	674	896	747	982	818
13	547	456	618	515	690	575	763	636	836	697
14	472	393	533	444	595	496	658	548	721	601
15	411	343	464	387	518	432	573	478	628	523
16	361	301	408	340	455	379	504	420	552	460

Safe loads given include weight of section.

Electric Wiring, etc. — During the progress of this part of the work, the superintendent must pay close attention, as the conduits are put in place, to see that they are laid properly, and all outlets left at the proper location; he should see that no more bends are put in a line of conduits than are absolutely necessary, and as the conduits are being put together he should see that the inside end of each piece is reamed out so there will be no burr to catch the steel fishing-wire or to tear the covering of the electric wire as it is pulled through. The different pieces of the conduit tubes should be screwed together so that they will butt in the centre of the coupling.

The quarter-bends in the tubing should not be less than a 3-inch radius. When the wires are run in the tubes the superintendent should see that no extreme force is required to pull them through and that the covering is in no way scratched or torn. He should see that all splices are well soldered and covered, and should permit no splice to be made in a straight run of wire.

The superintendent should provide himself with samples of the wires to be used so as to determine if the proper-sized conduits are being put in. The conduits should be large enough so that the wires can be easily drawn through them.

Electrical Terms, etc. — A broken circuit is one in which its conducting elements are disconnected in such a manner as to prevent the current from flowing.

A closed or completed circuit is one whose conducting elements are so connected as to allow the current to flow.

A circuit is said to be grounded when the earth or ground forms a part of the conducting path, and conducts the current into the earth.

AMPERE.—A current of water is the rate of flow, or the intensity or strength at which the water flows. We say, for instance, the water flows through a pipe at the rate of 1 gallon per second. Similarly the unit of the electric current is one coulomb per second. This is the ampere or unit rate of flow, or unit of current strength, or simply the unit of current of electricity.

In the case of the waterflow, we have no single word to express the strength of the current, but have to speak of the quantity and time.

OHM.—A pipe of small diameter offers a greater resistance to the flow of water than a pipe of larger dimension. So a wire

of small diameter offers more resistance to an electric current than a wire of larger diameter. If we double the cross-section of a wire we halve its resistance. If we double the length of a wire, we double its resistance. If we double the cross-section and double the length of a wire, the resistance remains the same. This law may be expressed thus: For a wire of a given substance the resistance is directly proportional to the length, and inversely proportional to the cross-section. The unit of electrical resistance is called an ohm.

The unit now universally adopted is called the international ohm and is the resistance offered by a column of pure mercury 106.3 centimeters in length and 1 square millimeter in sectional area at 32° Fahr., or the temperature of melting ice. These dimensions in inches would be 41.85 inches in length, and a sectional area of .00155 square inch.

In the table on page 482 are given various data respecting the copper wire used in electrical installations. In the first column is the gauge number by American wire-gauge; in the second column is the diameter as measured in mils (one mil one one-thousandth of an inch); the third column shows the area of cross-section in circular mils. It is usual to adopt this method for round wire instead of the old way of expressing the area in fractions of a square inch, in which case the diameter is squared and the product multiplied by .7854. If the second operation be omitted, and the diameter, as measured in thousandths of an inch, be only squared (or multiplied by itself), the result is expressed in circular thousandths or circular mils.

Example.—What is the area in circular mils of a wire $2\frac{1}{2}$ inches in diameter?

Answer.—$2\frac{1}{2}$ inches $=2500$ mils. $2500^2=2500\times2500=6{,}250{,}000$ circular mils.

The resistance of copper wire being low, a unit of length of 1000 feet is usually taken in tables of resistance, and this unit is considered in the eighth column.

The resistance of any length of conductor may be found by the following formula:

$$R=\frac{LR_1}{1000}.$$

Where R = required resistance;

L = length of conductor;

R_1 = resistance per 1000 feet of conductor.

TABLE OF DIMENSIONS AND RESISTANCES OF PURE COPPER WIRE.*

American Gauge, B. & S. No.	Diameter, Mills.	Area.		Weight and Length, Specific Gravity, 8.9.			Resistance at 75° Fahr.			
		Circular Mils ($d2$) 1 Mil = .001 Inch.	Square Inches, ($d2 \times .7854$)	Pounds per 1000 Feet.	Pounds per Mile.	Feet per Pound.	R Ohms per 1000 Feet.	Ohms per Mile.	Feet per Ohm.	Ohms per Pound.
0000	460.000	211600.00	166190	639.33	3375.7	1.56	.04906	.25903	20383	.000076736
000	409.640	167805.00	131790	507.01	2677.0	1.97	.06186	.32664	16165	.00012039
00	364.800	133079.40	104520	402.09	2123.0	2.49	.07801	.41187	12820	.00019423
0	324.950	105592.50	82932	319.04	1684.5	3.13	.09831	.51909	10409	.00030772
1	289.300	83694.20	65733	252.88	1335.2	3.95	.12404	.65490	8062.3	.00048994
2	257.630	66373.00	52130	200.54	1058.8	4.99	.15640	.82582	6393.7	.00078045
3	229.420	52634.00	41339	159.03	839.68	6.29	.19723	1.0414	5070.2	.0012406
4	204.310	41742.00	32784	126.12	665.91	7.93	.24869	1.3131	4021.0	.0019721
5	181.940	33102.00	25998	100.01	528.05	10.00	.31361	1.6558	3188.7	.0031361
6	162.020	26250.50	20617	79.32	418.81	12.61	.39546	2.0881	2528.7	.0049868
7	144.280	20816.00	16349	62.90	332.11	15.90	.49871	2.6331	005.2	.0079294
8	128.490	16509.00	12966	49.88	263.37	20.05	.62881	3.3201	1590.3	.012608
9	114.430	13594.00	10284	39.56	208.88	25.28	.79281	4.1860	1261.3	.020042
10	101.890	10381.00	8153.2	31.37	165.63	31.38	1.	5.2800	1000.0	.031380
11	90.742	8234.00	6467.0	24.88	137.37	40.20	1.2607	6.6568	793.18	.050682

12	80.808	6529.90	5128.6	19.73	104.18	50.69	1.5898	8.3940	629.02	.080585
13	71.961	5178.40	4067.1	15.65	82.632	63.91	2.0047	10.585	498.83	.12841
14	64.084	4106.80	3146.9	12.41	65.525	80.59	2.5908	13.680	385.97	.20880
15	57.068	3256.7	2557.8	9.84	51.956	101.63	3.1150	16.477	321.02	.31658
16	50.820	2582.9	2028.6	7.81	41.237	128.14	4.0191	21.221	248.81	.51501
17	45.257	2048.2	1608.6	6.19	32.683	161.59	5.0683	26.761	197.30	.81900
18	40.303	1624.3	1275.7	4.91	25.925	203.76	6.3911	33.745	156.47	1.3023
19	35.390	1252.4	983.64	3.78	20.051	264.26	8.2889	43.765	120.64	2.1904
20	31.961	1021.5	802.28	3.09	16.315	324.00	10.163	53.658	98.401	3.2926
21	28.462	810.10	636.25	2.45	12.936	408.56	12.815	67.660	78.037	5.2355
22	25.347	642.70	504.78	1.94	10.243	515.15	16.152	85.283	61.911	8.3208
23	22.571	509.45	400.12	1.54	8.1312	649.66	20.377	107.59	49.087	13.238
24	20.100	404.01	317.31	1.22	6.4416	819.21	25.695	135.67	38.918	21.050
25	17.900	320.40	251.64	.97	5.1216	1032.96	32.400	171.07	30.864	33.466
26	15.940	254.01	199.50	.77	4.0656	1302.61	40.868	215.79	24.469	35.235
27	14.195	201.50	158.26	.61	3.2208	1642.55	51.519	272.02	19.410	84.644
28	12.641	159.79	125.50	.48	2.5344	2071.22	64.966	343.02	15.393	134.56
29	11.257	126.72	99.526	.38	2.0064	2611.82	81.921	432.54	12.207	213.96
30	10.025	100.5	78.933	.30	1.5840	3293.97	103.30	545.39	9.6812	340.25
31	8.928	79.71	62.604	.24	1.2672	4152.22	127.27	671.99	7.8573	528.45
32	7.950	63.20	49.637	.19	1.0032	5236.66	164.26	867.27	6.0880	860.33
33	7.080	50.13	39.372	.15	.7920	6602.71	207.08	1093.4	4.8290	1367.3
34	6.304	39.74	31.212	.12	.6336	8328.30	261.23	1379.3	3.8281	2175.5
35	5.614	31.52	24.756	.10	.5280	10501.35	329.35	1738.9	3.0363	3458.5
36	5.000	25.000	19.635	.08	.4224	13238.83	415.24	2192.5	2.4082	5497.4
37	4.453	19.83	15.567	.06	.3168	16691.06	523.76	2765.5	1.9093	8742.1
38	3.965	15.72	12.347	.05	.2640	20854.65	660.37	3486.7	1.5143	13772
39	3.531	12.47	9.9739	.04	.2112	26302.23	832.48	4395.5	1.2012	21896
40	3.144	9.89	7.7676	.03	.1584	33175.94	1049.7	5542.1	.9527	34823

* Calculated on the basis of Dr. Matthiessen's standard, viz.: 1 mile of pure copper wire of $\frac{1}{16}$ inch diameter equals 13.59 ohms at 15.5° C. or 59.9° Fahr.

These tables are theoretically correct, but variations must be expected in practice.

Rule.—To find the resistance of any length of wire, divide that length in feet by 1000, and multiply by the figure giving the resistance of that wire per thousand feet, as found in the table on page 482.

VOLT.—The unit of electric pressure, or electromotive force, or difference of potential, is called the volt. We speak of an electromotive force of so many volts as we might speak of a head of water of so many feet, or of a steam pressure of so many pounds per square inch. Water may fall from a higher to a lower level, a certain vertical distance, say of 10 feet; so of electricity it is said to fall through a difference of potential of say 10 volts.

With a known resistance in ohms and a known strength of current in amperes, the electromotive force in volts is determined by Ohm's law, for, by transposing,

$$C=\frac{E}{R} \text{ may be written } E=CR.$$

WATT.—This unit of power is called the volt-ampere, or the watt. One watt equals $\frac{1}{746}$ of a horse-power, or 1 horse-power equals 746 watts. Hence it is expressed in electrical work thus:

$$\text{Horse-power}=\frac{\text{watts}}{746} \text{ or, watts}=\text{H.P.}\times 746.$$

As 1 watt is the product of 1 ampere and 1 volt, it can be seen that work can be done at the same rate with great current strength and low electromotive force, or with small current strength and high electromotive force; for instance, 100 amperes $\times$10 volts = 1000 watts, and 10 amperes $\times$ 100 volts = 1000 watts.

EQUIVALENTS OF ELECTRICAL UNITS.

1 Horse-power = 33,000 foot-pounds per minute.
1 Kilowatt = 44,235 foot-pounds per minute.
1 Horse-power = 746 watts.
1 Kilowatt = 1.34 H.P.
1 B.T.U. (British Thermal Unit) = 772 foot-pounds.

1 Watt = 44.236 foot-pounds per minute.
1 Watt = 2654.16 foot-pounds per hour.
1 H.P. = 42.746 B.T.U. per minute.
1 H.P. = 2564.76 B.T.U. per hour.
1 K.W. = 0.955 B.T U. per second.
1 K.W. = 57.3 B.T.U. per minute.
1 K.W. = 3438 B.T.U. per hour.
1 B.T.U. = 17.452 watt minutes.
1 B.T.U. = 0.2909 watt hours.

Latent heat of evaporation of water = 966 B.T.U.

Latent heat of melting of water = 142 B.T.U.

To evaporate 1 pound water from and at 212° = 16.859 K.W. minutes.

To evaporate 1 pound water from and at 212° = 0.281 K.W. hours.

Weight per cubic foot of water = 62.42 pounds.

Weight per gallon of water = 8.33 pounds.

Watts per Candle-power.	50 Volts.			52 Volts.			100 Volts.	
	3.1	3.5	4.0	3.1	3.5	4.0	3.1	3.5
8 C.P.	.496	.56	.64	.477	.538	.615	.248	.280
10 C.P.	.620	.70	.80	.596	.673	.769	.310	.350
16 C.P.	.992	1.12	1.28	.954	1.077	1.231	.496	.560
20 C.P.	1.240	1.40	1.60	1.192	1.346	1.538	.620	.700
24 C.P.	1.488	1.68	1.92	1.431	1.615	1.846	.744	.840
32 C.P.	1.984	2.24	2.56	1.908	2.154	2.461	.992	1.120

Watts per Candle-power.						Series Ry. Lamps.		
	104 Volts.		110 Volts.		220 V.	500 V.	550 V.	600 V.
	3.1	3.5	3.1	3.5	4.0	4.0	4.0	4.0
8 C.P.	.238	.269	.225	.255	.145	.064	.058	.053
10 C.P.	.298	.337	.282	.318	.182	.080	.073	.067
16 C.P.	.477	.538	.451	.520	.291	.128	.116	.107
20 C.P.	.596	.673	.564	.636	.363	.160	.145	.133
24 C.P.	.715	.808	.676	.764	.436	.192	.175	.160
32 C.P.	.954	1.077	.902	1.018	.582	.256	.233	.213

Amperes per Lamp.—The above table is arranged to show the amperes per lamp for lamps of different candle-powers and efficiencies at various voltages. The upper row of figures shows the voltage, the second shows the watts per candle-power,

or efficiency, and the figures below show the corresponding amperes per lamp for different candle-powers.

This table is made in accordance with the best information obtainable from manufacturers on the efficiency of standard lamps in use. Lamps of other efficiencies are on the market, but those shown are standard for good practice at the present time.

INCANDESCENT WIRING TABLE.

The table on page 487 is arranged to enable wiremen to select the right sizes of wire for service connections and inside work. The figures at the top indicate distance in feet to centre of distribution, in reality half the length of the circuit; the four columns at the left showing the number of 16-candle-power lamps at various voltages; the other figures showing the sizes of wire, Brown & Sharpe gauge, to be used for distributing the number of lamps stated at the distances indicated and with the loss of 1 volt.

For example: To distribute 30 lamps of 110 volts at a distance of 80 feet with a loss of 1 volt. In column of 110-volt lamps find the number 30, then follow the same line of figures to the right until the column headed 80 is reached, and it appears that No. 6 wire must be used.

The same table may be used for other losses than 1 volt by dividing the given number of lamps by the number of volts to be lost, then with this product proceed as before in the table.

For example: To distribute 30 lamps of 110 volts at a distance of 80 feet with a loss of 2 volts, divide 30 by 2, which gives 15, then find 15 in the column headed 110 volts and follow the same line of figures to the right until column headed 80 is reached, and it is found that No. 8 wire must be used.

No wire smaller than No. 14 is shown in the table, as the National Board of Fire Underwriters prohibits the use of a smaller size. Odd sizes smaller than No. 5 are not commercial and are therefore omitted.

In calculating the sizes of wire as shown in the incandescent wiring table a formula (*A*) has been used in which there is a constant 10.7, the number of circular mils in a copper wire which would have a resistance of 1 ohm for 1 foot of length. 1 ampere through 1 ohm resistance loses 1 volt. To determine the size of wire necessary for carrying a given current a given distance in feet, multiply the number of feet by 2 to obtain the

INCANDESCENT WIRING TABLE.

SIXTEEN-CANDLE-POWER LAMPS. LOSS, ONE VOLT.

Sizes of Wire are by B. & S. Gauge.

52 Volt 3½ Watt Lamps.	110 Volt 3½ Watt Lamps.	220 Volt 4 Watt Lamps.	550 Volt 4 Watt Lamps.	Distance in Feet to Centre of Distribution.																
				20′	25′	30′	35′	40′	45′	50′	60′	70′	80′	90′	100′	120′	140′	160′	180′	200′
1	2	3	9	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	14	12
2	4	7	18	14	14	14	14	14	14	14	14	14	14	14	12	12	12	10	10	10
3	6	11	28	14	14	14	14	14	14	14	14	12	12	12	10	10	10	8	8	8
4	8	15	37	14	14	14	14	14	14	12	12	12	10	10	10	8	8	8	8	6
5	10	18	46	14	14	14	14	12	12	12	10	10	10	10	8	8	8	6	6	6
6	12	22	56	14	14	14	12	12	12	10	10	10	8	8	8	8	6	6	6	6
7	15	26	65	14	14	12	12	12	10	10	10	8	8	8	8	6	6	6	5	5
8	17	30	74	14	12	12	12	10	10	10	8	8	8	8	6	6	6	5	5	4
9	19	33	83	14	12	12	10	10	10	10	8	8	8	6	6	6	5	5	4	4
10	21	37	93	12	12	12	10	10	10	8	8	8	6	6	6	5	5	4	4	3
12	25	44	111	12	10	10	10	8	8	8	8	6	6	6	5	5	4	3	3	2
14	30	52	130	12	10	10	8	8	8	8	6	6	6	5	5	4	3	3	2	2
16	34	59	148	10	10	8	8	8	8	6	6	6	5	5	4	3	3	2	2	1
18	38	66	167	10	8	8	8	8	6	6	6	5	5	4	4	3	2	2	1	1
20	42	74	185	10	8	8	8	6	6	6	5	5	4	4	3	2	2	1	1	0
25	53	92	232	8	8	6	6	6	6	5	5	4	3	3	2	1	1	0	0	00
30	63	111	278	8	6	6	6	5	5	5	4	3	2	2	1	1	0	0	00	00
35	74	130	324	6	6	6	5	5	4	4	3	2	2	1	1	0	00	00	000	000
40	85	148	371	6	6	6	5	4	4	3	2	2	1	1	0	00	00	000	000	0000
45	95	166	428	5	5	5	4	4	3	3	2	1	1	0	0	00	000	000	0000	0000
50	106	185	464	5	5	4	4	3	3	2	1	1	0	0	00	000	000	0000	0000	....
55	116	203	510	4	4	4	3	3	2	2	1	0	0	00	00	000	0000	0000	....	....
60	127	222	557	4	4	4	3	2	2	1	1	0	00	00	000	000	0000	0000	....	....
65	138	240	603	3	3	3	3	2	2	1	0	0	00	00	000	0000	0000	....	....	....
70	148	260	650	3	3	3	2	2	1	1	0	00	00	000	000	0000	....	....	....	....
75	159	277	696	2	2	2	2	1	1	0	0	00	000	000	0000	0000	....	....	....	....
80	170	296	742	2	2	2	2	1	1	0	00	00	000	000	0000	....	....	....	....	....
90	191	333	835	1	1	1	1	1	0	0	00	000	000	0000	0000	....	....	....	....	....
100	212	370	928	1	1	1	1	0	0	00	000	000	0000	0000	....	....	....	....	....	....

TABLE FOR FORMULAS, A, B, AND C.

Feet to End of Circuit.	Feet × 2 × 10.70	Feet to End of Circuit.	Feet × 2 × 10.70	Feet to End of Circuit.	Feet × 2 × 10.70
5	107	300	6,420	690	14,766
10	214	305	6,527	700	14,980
15	321	310	6,634	710	15,194
20	428	315	6,741	720	15,408
25	535	320	6,848	730	15,622
30	642	325	6,955	740	15,836
35	749	330	7,062	750	16,050
40	856	335	7,169	760	16,264
45	963	340	7,276	770	16,478
50	1070	345	7,383	780	16,692
55	1177	350	7,490	790	16,906
60	1284	355	7,597	800	17,120
65	1391	360	7,704	810	17,334
70	1498	365	7,811	820	17,548
75	1605	370	7,918	830	17,762
80	1712	375	8,025	840	17,976
85	1819	380	8,132	850	18,190
90	1926	385	8,239	860	18,404
95	2033	390	8,346	870	18,618
100	2140	395	8,453	880	18,832
105	2247	400	8,560	890	19,046
110	2354	405	8,667	900	19,260
115	2461	410	8,774	910	19,474
120	2568	415	8,881	920	19,688
125	2675	420	8,988	930	19,902
130	2782	425	9,095	940	20,116
135	2889	430	9,202	950	20,330
140	2996	435	9,309	960	20,544
145	3103	440	9,416	970	20,758
150	3210	445	9,523	980	20,972
155	3317	450	9,630	990	21,186
160	3424	455	9,737	1000	21,400
165	3531	460	9,844	1010	21,614
170	3638	465	9,951	1020	21,828
175	3745	470	10,058	1030	22,042
180	3852	475	10,165	1040	22,256
185	3959	480	10,272	1050	22,470
190	4066	485	10,379	1060	22,684
195	4173	490	10,486	1070	22,898
200	4280	495	10,593	1080	23,112
205	4387	500	10,700	1090	23,326
210	4494	510	10,914	1100	23,540
215	4601	520	11,128	1110	23,754
220	4708	530	11,342	1120	23,968
225	4815	540	11,556	1130	24,182
230	4922	550	11,770	1140	24,396
235	5029	560	11,984	1150	24,610
240	5136	570	12,198	1160	24,824
245	5243	580	12,412	1170	25,038
250	5350	590	12,626	1180	25,252
255	5457	600	12,840	1190	25,466
260	5564	610	13,054	1200	25,680
265	5671	620	13,268	1210	25,894
270	5778	630	13,482	1220	26,108
275	5885	640	13,696	1230	26,322
280	5992	650	13,910	1240	26,536
285	6099	660	14,124	1250	26,750
290	6206	670	14,338	1260	26,964
295	6313	680	14,552	1270	27,178

TABLE FOR FORMULAS, A, B, AND C.

Feet to End of Circuit.	Feet × 2 × 10.70	Feet to End of Circuit.	Feet × 2 × 10.70	Feet to End of Circuit.	Feet × 2 × 10.70
1280	27 392	1870	40,018	4200	89,880
1290	27 606	1880	40,232	4250	90,959
1300	27 820	1890	40,446	4300	92,020
1310	28,034	1900	40,660	4350	93,090
1320	28,248	1910	40,874	4400	94,160
1330	28,462	1920	41,088	4450	95,230
1340	28,676	1930	41,302	4500	96,300
1350	28,890	1940	41,516	4550	97,370
1360	29,104	1950	41,730	4600	98,440
1370	29,318	1960	41,944	4650	99,510
1380	29,532	1970	42,158	4700	100,580
1390	29,746	1980	42,372	4750	101,650
1400	29,960	1990	42,586	4800	102,720
1410	30,174	2000	42,800	4850	103,790
1420	30,388	2050	43,870	4900	104,860
1430	30,602	2100	44,940	4950	105,930
1440	30,816	2150	46,010	5000	107,000
1450	31,030	2200	47,080	5050	108,070
1460	31,244	2250	48,150	5100	109,140
1470	31,458	2300	49,220	5150	110,210
1480	31,672	2350	50,290	5200	111,280
1490	31,886	2400	51,360	5250	112,350
1500	32,100	2450	52,430	5300	113,420
1510	32,314	2500	53,500	5350	114,490
1520	32,528	2550	54,570	5400	115,560
1530	32,742	2600	55,640	5450	116,630
1540	32,956	2650	56,710	5500	117,700
1550	33,170	2700	57,780	5550	118,770
1560	33,384	2750	58,850	5600	119,840
1570	33,598	2800	59,920	5650	120,910
1580	33,812	2850	60,990	5700	121,980
1590	34,026	2900	62,060	5750	123,050
1600	34,240	2950	63,130	5800	124,120
1610	34,454	3000	64,200	5850	125,190
1620	34,668	3050	65,270	5900	126,260
1630	34,882	3100	66,340	5950	127,330
1640	35,096	3150	67,410	6000	128,400
1650	35,310	3200	68,480		
1660	35,524	3250	69,550	Miles.	
1670	35,738	3300	70,620	½	564,96
1680	35,952	3350	71,690	1	112,992
1690	36,166	3400	72,760	1½	169,488
1700	36,380	3450	73,830	2	225,984
1710	36,594	3500	74,900	2½	282,480
1720	36,808	3550	75,970	3	338,976
1730	37,022	3600	77,040	3½	395,472
1740	37,236	3650	78,110	4	451,968
1750	37,450	3700	79,180	4½	508,464
1760	37,664	3750	80,250	5	564,960
1770	37,878	3800	81,320	5½	621,456
1780	38,092	3850	82,390	6	677,952
1790	38,306	3900	83,460	6½	734,448
1800	38,520	3950	84,530	7	790,944
1810	38,734	4000	85,600	7½	847,440
1820	38,948	4050	86,670	8	903,936
1830	39,162	4100	87,740	8½	960,432
1840	39,376	4150	88,810	9	1,016,928
1850	39,590			9½	1,073,424
1860	39,804			10	1,129,920

$$(A)\quad \frac{\text{Feet}\times 2\times 10.7\times \text{amperes}}{\text{Volts lost}}=\text{circular mils.}$$

$$(B)\quad \frac{\text{Feet}\times 2\times 10.7\times \text{amperes}}{\text{Circular mils}}=\text{volts lost.}$$

$$(C)\quad \frac{\text{Circular mils}\times \text{volts lost}}{\text{Feet}\times 2\times 10.7}=\text{amperes.}$$

actual length of circuit, multiply this product by the constant 10.7 and it will give the circular mils necessary for 1 ohm resistance, multiply this by the amperes and it gives the circular mils necessary for the loss of 1 volt. Divide this last result by the volts lost and it gives the circular mils necessary. Hence the formula A.

By simply transposing the terms we obtain formula B, which can be used to determine the volts lost in a given length of wire of certain size carrying a certain number of amperes.

Again, by another change in the terms, we obtain formula C, which shows the number of amperes which a wire of given size and length will carry at a given number of volts lost.

The table on pages 488, 489 has been arranged for the purpose of saving time in the use of these formulæ. It shows the result of Feet$\times$2$\times$10.7 for various distances over which it may be desired to transmit current.

A few examples will assist in showing the use of the formulæ and tables.

Suppose we wish to distribute 300 16-candle-power 3.5 watt lamps of 110 volts at a distance of 490 feet with a loss of 10 per cent:

Using formula A,

490 feet$\times$2$\times$10.7 (find it in table on page 488) = 10.486.

300 lamps of 110 volts = 152.7 amperes.

(See table, page 485, for amperes per lamp and multiply by 300.)

10 per cent loss on 110-volt system = 12.22 volts. (See table on page 491.)

10,486$\times$152.7 amperes = 1,601,212 circular mils $\div$ 12.22 volts lost = 131,030 circular mils.

Table on page 482 shows the size of wire for this number of circular mils to be 00.

To check this and determine exactly the volts lost in this circuit by using No. 00 wire, use formula B, as follows:

10,486$\times$152.7 amperes = 1,601,212 $\div$ 133,079 circular mils = 12.03 volts lost.

VOLTS LOST AT DIFFERENT PER CENT DROP.

Voltage at Lamp or Distribution Point, Top Row.

Volts.	52	75	100	110	220	400	500	600	800	1000	1200	2000
½%	.261	.376	.502	.552	1.10	2.01	2.51	3.01	4.02	5.02	6.03	10.05
1%	.525	.757	1.01	1.11	2.22	4.04	5.05	6.06	8.08	10.10	12.12	20.2
1½%	.2918	1.14	1.52	1.67	3.35	6.09	7.61	9.13	12.1	15.2	18.2	30.4
2%	1.06	1.53	2.04	2.24	4.48	8.16	10.2	12.2	16.3	20.4	24.4	40.8
2½%	1.33	1.92	2.56	2.82	5.64	10.25	12.8	15.3	20.5	25.6	30.7	51.2
3%	1.61	2.31	3.09	3.40	6.80	12.37	15.4	18.5	24.7	30.9	37.1	61.8
4%	2.16	3.12	4.16	4.58	9.16	16.66	20.8	24.9	33.3	41.6	49.9	83.3
5%	2.73	3.94	5.26	5.78	11.57	21.05	26.3	31.5	42.1	52.6	63.1	105.
6%	3.31	4.78	6.38	7.02	14.04	25.53	31.9	38.2	51.	63.8	76.5	127.
7%	3.91	5.64	7.52	8.27	16.55	30.10	37.6	45.1	60.2	75.2	90.3	150.
8%	4.52	6.52	8.69	9.56	19.13	34.78	43.4	52.1	69.5	86.9	104.	173.
9%	5.14	7.41	9.89	10.87	21.75	39.56	49.4	59.3	79.1	98.9	118.	197.
10%	5.77	8.33	11.11	12.22	24.44	44.44	55.5	66.6	88.8	111.	133.	222.
12%	7.09	10.22	13.63	14.99	29.99	54.54	61.7	74.1	98.8	123.	148.	247.
13%	7.76	11.10	14.94	16.43	32.87	59.76	68.1	81.8	109.	136.	163.	272.
14%	8.46	12.20	16.27	17.90	35.81	65.1	74.7	89.6	119.	149.	179.	298.
15%	9.17	13.23	17.64	19.41	38.82	70.5	81.3	97.6	130.	162.	195.	325.
20%	13.	18.75	25.	27.50	55.	100.	88.2	105.	141.	176.	211.	352.
25%	17.33	25.	33.33	36.66	73.33	133.	125.	150.	200.	250.	300.	400.
30%	....	....	....	....	....	....	166.	200.	266.	333.	400.	666.

The above table shows the loss in voltage between dynamos and distribution point at different per cents and for various voltages.

By adding the volts given in the table to the voltage at motor or lamp the result shows the voltage necessary at dynamo for voltage required at point of distribution

The following table is arranged to show the amperes per motor at different voltages for several sizes of motors at efficiencies obtained in ordinary practice.

AMPERES PER MOTOR.

H.P.	Per Cent Efficiency.	Watts.	Volts.								
			110	115	120	125	220	250	500	525	550
¾	65	860	7.82	7.48	7.17	6.88	3.91	3.44	1.72	1.64	1.56
1	65	1148	10.4	9.98	9.57	9.18	5.22	4.59	2.30	2.19	2.09
2	65	2295	20.8	20.0	19.1	18.4	10.4	9.18	4.59	4.37	4.17
2½	75	2487	22.6	21.6	20.7	19.9	11.3	9.95	4.97	4.74	4.52
3½	75	3480	31.6	30.3	29.0	27.8	15.8	13.9	6.96	6.63	6.33
5	80	4662	42.4	40.5	38.8	37.3	21.2	18.6	9.32	8.88	8.48
7½	80	6994	63.6	60.8	58.3	56.0	31.8	28.0	14.0	13.3	12.7
10	85	8776	79.8	76.3	73.1	70.2	39.9	35.1	17.6	16.7	16.0
15	85	13165	120.	114.	110.	105	59.8	52.6	26.3	25.1	23.9
20	90	16578	151.	144.	138.	133.	75.4	66.3	33.2	31.6	30.1
25	90	20722	188.	180.	173.	166.	94.2	82.9	41.4	39.5	37 7
30	90	24867	226.	216.	207.	199.	113.	99.4	49.7	47.4	45.2
40	90	33155	301.	288.	276.	265.	151.	133.	66.3	63.2	60.3
50	90	41444	377.	360.	345.	332.	188.	166.	82.9	79.0	75.4
70	90	58022	528.	505.	484.	464.	264.	232.	116.	111.	106.
90	90	74600	678.	649.	622.	597.	339.	298.	149.	142.	136.
100	93	80215	729.	697.	668.	642.	365.	321.	160.	153.	146.
125	93	100269	912.	872.	836.	802.	456.	401.	200.	191.	182.
150	93	120323	1094.	1046.	1003.	963.	547.	481.	241.	229.	219.

Suppose it is desired to distribute 1000 lamps at a distance of 1950 feet by 3-wire system, viz., 220 volts, with a loss of 10 per cent:

Using formula A,

1950 feet$\times 2 \times$10.7 (see table on page 489) = 41,730.

1000 lamps on 220-volt system = 291 amperes.

(See table on page 485 for amperes per lamp and multiply by 1000.)

10 per cent on 220-volt system = 24.44 volts lost. (See table on page 491.)

41,730$\times$291 amperes = 12,143,430 $\div$ 24.44 volts lost = 496,867 circular mils.

500,000 circular mils, the nearest commercial size, should be used.

Check this as before by formula B.

41,730$\times$291 amperes = 12,143,430 $\div$ 500,000 circular mils = 24.29 volts lost.

Suppose we wish to deliver 100 horse-power to a 500-volt motor at a distance of 4850 feet with 10 per cent loss:

Again using formula A,

4850 feet$\times 2 \times$10.7 = 103,790.

100 horse-power at 500 volts = 160 amperes. (See table on page 492.)

10 per cent loss on 500-volt system = 55.5 volts. (See table on page 491.)

103,790$\times$160 amperes = 16,606,400 $\div$ 55.5 volts = 299,215 circular mils.

300,000 circular mils cable should be used.

Check this as before by formula B.

103,790$\times$160 amperes = 16,606,400 $\div$ 300,000 circular mils = 55.35 volts lost.

To ascertain how many amperes could be carried to a distance of 4850 feet with 500 volts with 10 per cent loss, use formula C:

4850 feet$\times 2 \times$10.7 = 103,790.

10 per cent loss on 500-volt system = 55.5 volts.

300,000 circular mils$\times$55.5 volts lost $\div$ 103,790 = 160.42 amperes, which, as will appear by reference to table on page 492, will permit the use of 100-horse-power motor.

The following table gives the gauge and safe carrying capacity of copper. wire

GAUGES IN CIRCULAR MILS AND SAFE CARRYING CAPACITY

d^2 Circular Mils.	B. & S. Brown & Sharpe Gauge.	B.W.G. Birmingham Wire Gauge.	E.S.G. Edison Standard Gauge.	Safe Carrying Capacity. Wire heated to 30° F. above Temperature of Surrounding Air. Number of Amperes.	Number of 55-volt Lamps, 16 C.P.	Number of 75-volt Lamps, 16 C.P.	Number of 110-volt Lamps, 16 C.P.
220,000	....	....	220	203	203	278	406
211,600	0000	....	....	197.3	197	270	395
206,116	....	0000	....	193.5	193	264	387
200,000	....	....	200	189.15	189	259	378
190,000	....	....	190	182	182	249	364
180,625	....	000	....	179.3	179	245	359
180,000	....	....	180	174.8	175	240	330
170,000	....	....	170	167.4	167	229	335
167,805	000	....	....	165.8	166	227	332
160,000	....	....	160	160	160	219	320
150,000	....	....	150	152.5	152	208	305
144,400	....	00	....	148.2	148	203	296
140,000	....	....	140	114.8	145	199	290
133,079	00	....	....	139.4	139	190	279
130,000	....	....	130	136.9	137	188	274
120,000	....	....	120	129	129	177	258
115,600	....	....	....	125.4	125	171	251
110,000	....	....	110	120.8	121	166	242
105,592	0	....	....	117.2	117	160	234
100,000	....	....	100	112.5	112	153	225
95,000	....	....	95	108.2	108	148	216
90,000	....	1	90	103.9	104	142	208
85,000	....	....	85	99.5	99	136	199
83,694	1	....	....	98.4	98	134	197
80,656	....	2	....	95.7	96	131	191
80,000	....	....	80	95.1	95	130	190
75,000	....	....	75	90.6	91	125	181
70,000	....	....	70	86	86	118	172
67,081	....	3	....	84	84	115	168
66,373	2	....	....	83.1	83	114	166
65,000	....	....	65	81.4	81	111	163
60,000	....	....	60	78.4	78	107	157
56,644	....	4	....	73.4	73	100	147
55,000	....	....	55	71.8	72	99	144
52,634	3	....	....	69.5	69	94	139
50,000	....	....	50	66.8	67	92	134
48,400	....	5	....	65.2	65	89	131
45,000	....	....	45	61.7	62	85	123
41,742	4	....	....	58.4	58	79	117

GAUGES IN CIRCULAR MILS AND SAFE CARRYING CAPACITY—(*Continued*).

d^2 Circular Mils.	B. & S. Brown & Sharpe Gauge.	B.W.G. Birmingham Wire Gauge.	E.S.G. Edison Standard Gauge.	Safe Carrying Capacity. Wire heated to 30° F. above Temperature of Surrounding Air. Number of Amperes.	Number of 55-volt Lamps, 16 C.P.	Number of 75-volt Lamps, 16 C.P.	Number of 110-volt Lamps, 16 C.P.
41,209	....	6	....	57.8	58	79	116
40,000	....	....	40	56.5	56	77	113
35,000	....	....	35	51.1	51	70	102
33,102	5	....	....	49.1	49	67	98
32,400	....	7	....	48.3	48	66	97
30,000	....	....	30	46.6	46	63	93
27,225	....	8	....	42.4	42	57	85
26,250	6	....	....	41.2	41	56	82
25,000	....	....	25	39.7	40	55	79
21,904	....	9	....	36	36	49	72
20,816	7	....	....	34.6	34	47	69
20,000	....	....	20	33.6	33	45	67
17,956	....	10	....	31	31	42	62
16,509	8	....	....	29.1	29	40	58
15,000	....	....	15	27.1	27	37	54
14,400	....	11	....	26.3	26	36	52
13,094	9	....	....	24.4	24	33	49
12,000	....	....	12	22.9	23	31	46
11,881	....	12	....	22.7	23	31	46
10,381	10	....	....	20.5	20	27	41
9,025	....	13	....	18.5	18	25	37
8,234	11	....	....	17.3	17	23	34
8,000	....	....	8	16.9	17	23	34
6,889	....	14	....	15.1	15	20	30
6,530	12	....	....	14.5	14	19	29
5,184	....	15	....	12.2	12	16	24
5,178	13	....	....	12.2	12	16	24
5,000	....	....	5	11.9	12	16	24
4,225	....	16	....	10.5	10	14	21
4,107	14	....	....	10.2	10	14	20
3,364	....	17	....	8.8	9	12	17
3,257	15	....	....	8.6	9	12	17
3,000	....	....	3	8.1	8	11	16
2,583	16	....	....	7.2	7	10	14
2,401	....	18	....	6.8	7	10	14

1. In this table it is estimated that 1 55-volt, 16-candle-power lamp requires about 1 ampere of current; 1 75-volt, 16-candle-power lamp requires about 0.73 ampere of current; 1 110-volt, 16-candle-power lamp requires about 0.5 ampere of current.

2. Lamps supposed to be in multiple arc. On the 3-wire system the same current in amperes will suffice for a series of two lamps. Hence twice the number of lamps as given in the above table can be safely carried on the same size wires.

CONDUCTORS AND INSULATORS.—Bodies in which the electric current moves freely are called conductors, and those in which it does not move freely are called insulators. There is, however, no substance so good a conductor as to be void of resistance, and there is no substance of so high a resistance as to be strictly a non-conductor.

In the following list the substances named are placed in order, each conducting better than those below it in the list:

Silver (best conductor) Copper Gold Aluminum Zinc Platinum Iron Tin Lead Nickel Mercury Charcoal Acids Water	Good conductors.
The body Cotton Dry wood Marble Paper Oils	Partial conductors.
Porcelain Wool Silk Resin Gutta-percha Shellac Ebonite Paraffine Glass Dry air (worst conductor).	Non-conductors or insulators.

WIRING FORMULÆ AS GIVEN BY THE NATIONAL ELECTRIC CODE.

For a complete set of rules the superintendent should provide himself with this Code, which can be secured from the Mutual Fire Insurance Companies, Boston.

General Wiring Formulæ.

$$V=\frac{D\times W\times R\times B}{E\times A}, \quad \text{or} \quad V=\frac{L\times E\times B}{100}.$$

$$A=\frac{D\times W\times R\times B}{E\times V}, \quad \text{or} \quad A=\frac{D\times W\times R\times 100}{L\times E^2}.$$

$$C=\frac{W\times T}{E}.$$

$$L=\frac{D\times W\times R\times 100}{E^2\times A}.$$

$$P=\frac{D^2\times W\times R\times S}{L\times E^2\times 10{,}000}, \quad \text{or} \quad P=\frac{D\times S\times A}{1{,}000{,}000}.$$

V = volts drop in line.
D = distance between the two points, in feet along the wires.
W = total power *delivered*, in watts.
E = voltage at *receiving* end of line.
A = area of cross-section of wire, in circular mils.

The area in circular mils of B. & S. guage sizes from No. 10 to No. 0000 inclusive will be found in the table on page 500. For wires smaller than these, see table on page 505.

C = current in each wire, in amperes.
L = loss in line, in per cent of W.
P = total pounds of copper in line.
R = a constant, for value of which see table on page 500.
S = " " " " " " " " " " "
T = " " " " " " " " " " "
B = " " " " " " " " " " "

For direct-current systems, $R=21.6$, $B=1.00$, $T=1.00$, and $W=C\times E$, so that the first two of the above formulæ reduce to $V=\frac{D\times C\times 21.6}{A}$, and $A=\frac{D\times C\times 21.6}{V}$.

In a balanced three-wire, two-phase, alternating-current system, the current in the middle wire is 1.41 times that in each

outside wire, the current in the outside wires being computed from the formula as if the system was a four-wire one.

When the power factor cannot be accurately determined, it may be assumed to be as follows for any alternating-current system operating under average conditions: lighting, with no motors, 95 per cent; lighting and motors together, 85 per cent; motors only, 80 per cent.

The values of B are for wires 18 inches apart, centre to centre, and are sufficiently accurate for all practical purposes, provided that the reactance of the line is not excessive or the line loss unusually high. They represent the true values at 10 per cent line loss; are close enough for all losses less than 10 per cent; and are often close enough for losses considerably above 10 per cent, at least for frequencies up to forty cycles. Where the conductors of a circuit are less than 18 inches apart, the value of B is less than that given in the table, and if they are close together, as with multiple conductor cable, B becomes equal to unity and can be omitted from the formula.

The following examples are given to show how the different formulæ are to be applied:

1. What size wire is needed to transmit current 200 feet to a centre of distribution for 60 incandescent lamps on a 110-volt direct-current system, with a drop of 3 per cent, which is an actual drop of 3.3 volts?

The table on page 485 shows that a 16 c. p. lamp at 110 volts takes 0.52 of an ampere, and 60 lamps would therefore take 31.2 amperes.

Hence $D=200$, $C=31.2$, and $V=3.3$, from which, using the simplified formula for direct-current, we have

$$A=\frac{200\times 31.2\times 21.6}{3.3}=40{,}840.$$

From the table on page 500, we see that the nearest B. & S. gauge size above this is No. 4, which is the proper size to use.

2. What is the current in each wire of a three-phase circuit feeding two motors developing 20 H.P. each, the voltage at the motors being 550?

40 H.P. $=40\times 746$ watts $=29{,}840$ watts. Assuming a power factor of 85 per cent (see note above), we find from the table that the value of T for this power factor on a three-phase,

three-wire system is 0.68. Then from the formula, we have

$$C = \frac{29{,}840 \times 0.68}{550} = 36.9 \text{ amperes.}$$

3. In a two-phase, 60-cycle transmission line, with four No. 2 B. & S. gauge wires 18 inches apart, supplying lighting transformers at a point one and five-eighths miles from the generating station, what must be the voltage at the generator switchboard to give a voltage of 2080 at the transformers when the load on the transformers is 188 K.W.?

$1\frac{5}{8}$ miles = 8580 feet, and 188 K.W. = 188,000 watts. Hence $D = 8580$, $W = 188{,}000$, $E = 2080$; and from the table $R = 12.00$, $A = 66{,}600$, and $B = 1.18$, assuming a power factor of 95 per cent (see notes on page 498).

Inserting these values in the formulæ for L and V, we have

$$L = \frac{8580 \times 188{,}000 \times 12 \times 100}{(2080)^2 \times 66{,}600} = 6.72 \text{ and}$$

$$V = \frac{6.72 \times 2080 \times 1.18}{100} = 165 \text{ volts.}$$

Therefore the voltage at the generator must be $2080 + 165 = 2245$.

The following rules for electric wiring, etc., are taken from the "National Electric Code," and every superintendent should have a copy of this code, which can be obtained from the Mutual Fire Insurance Companies, Boston, Mass. The rules referred to in the following extract will be found in the above code.

OUTSIDE WORK.

12. Wires.—*a*. Service wires must have an *approved* rubber insulating covering. (See Rule 41.) Line wires, other than services, must have an *approved* weather-proof or rubber insulating covering. (See Rules 41 and 44.) All tie wires must have an insulation equal to that of the conductors which they confine.

b. Must be so placed that moisture cannot form a cross connection between them not less than a foot apart, and not in contact with any substance other than their insulating supports

System.	Values of S.	Values of R. Per Cent Power Factor.					Values of T. Per Cent Power Factor.				
		100	95	90	85	80	100	95	90	85	80
Single-phase	6.04	21.60	24.00	26.60	30.00	33.80	1.00	1.05	1.11	1.17	1.25
Two-phase (four-wire)	12.08	10.80	12.00	13.30	15.00	16.90	.50	.53	.55	.59	.62
Three-phase (three-wire)	9.06	10.80	12.00	13.30	15.00	16.90	.58	.61	.64	.68	.72

No. of Wire, B. & S. Gauge.	Area Wire, Circular Mils.	Weight of Bare Wire per 1000 Feet, Pounds.	Resistance of Wire per 1000 Feet at 25° C. Ohms.	Values of B (for Wires 18 Inches Apart). 25 Cycles. Per Cent Power Factor.				40 Cycles. Per Cent Power Factor.				60 Cycles. Per Cent Power Factor.				125 Cycles. Per Cent Power Factor.				No. of Wire, B. & S. Gauge.
				95	90	85	80	95	90	85	80	95	90	85	80	95	90	85	80	
0000	212,000	641	.0499	1.23	1.29	1.33	1.34	1.52	1.53	1.61	1.67	1.62	1.84	1.99	2.09	2.35	2.86	3.24	3.49	0000
000	168,000	509	.0628	1.18	1.22	1.24	1.24	1.40	1.41	1.48	1.51	1.49	1.66	1.77	1.95	2.08	2.48	2.77	2.94	000
00	133,000	403	.0794	1.14	1.16	1.16	1.16	1.25	1.32	1.35	1.37	1.34	1.52	1.60	1.66	1.86	2.18	2.40	2.57	00
0	106,000	320	.0997	1.10	1.11	1.10	1.09	1.19	1.24	1.26	1.26	1.31	1.40	1.46	1.49	1.71	1.96	2.13	2.25	0
1	83,500	253	.126	1.07	1.07	1.05	1.03	1.14	1.17	1.18	1.17	1.24	1.30	1.34	1.36	1.56	1.75	1.88	1.97	1
2	66,600	202	.159	1.05	1.04	1.02	1.00	1.11	1.12	1.12	1.10	1.18	1.23	1.25	1.26	1.45	1.60	1.70	1.77	2
3	52,400	159	.202	1.03	1.02	1.00	1.00	1.07	1.08	1.07	1.05	1.14	1.17	1.18	1.17	1.35	1.46	1.53	1.57	3
4	41,600	126	.254	1.02	1.00	1.00	1.00	1.05	1.06	1.03	1.00	1.11	1.12	1.11	1.10	1.27	1.35	1.40	1.43	4
5	33,100	100	.319	1.00	1.00	1.00	1.00	1.03	1.01	1.00	1.00	1.08	1.08	1.06	1.04	1.21	1.27	1.30	1.31	5
6	26,200	79.5	.403	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.05	1.04	1.02	1.00	1.16	1.20	1.21	1.21	6
7	20,700	62.8	.510	1.00	1.00	1.00	1.00	1.01	1.00	1.00	1.00	1.03	1.02	1.00	1.00	1.12	1.14	1.14	1.13	7
8	16,600	50.4	.635	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.02	1.00	1.00	1.00	1.09	1.10	1.09	1.07	8
9	13,000	39.4	.813	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.06	1.06	1.04	1.02	9
10	10,400	31.5	1.01	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.04	1.03	1.00	1.00	10

Wooden blocks to which insulators are attached must be covered over their entire surface with at least two coats of water-proof paint.

c. Must be at least seven feet above the highest point of flat roofs and at least one foot above the ridge of pitched roofs over which they pass or to which they are attached.

d. Must be protected by dead insulated guard irons or wires from possibility of contact with other conducting wires or substances to which current may leak. Especial precautions of this kind must be taken where sharp angles occur, or where wires of any other systems might possibly come in contact with electric-light or power wires.

e. Must be provided with petticoat insulators of glass or porcelain. Porcelain knobs or cleats or rubber hooks will not be approved.

f. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered to insure preservation, and covered with an insulation equal to that on the conductors.

g. Must, where they enter buildings, have drip loops outside, and the holes through which the conductors pass must be bushed with non-combustible, non-absorptive, insulating tubes, slanting upward toward the inside.

h. Telegraph, telephone, and other signal wires must not be placed on the same cross-arm with electric-light or power wires, and when placed on the same pole with such wires, the distance between the two inside pins on each cross-arm must not be less than twenty-six inches.

i. The metallic sheaths of cables must be permanently and effectively connected to "earth."

Trolley Wires.—j. Must not be smaller than No. 0 B. & S. gauge copper or No. 4 B. & S. guage silicon bronze, and must readily stand the strain put upon them when in use.

k. Must have a double insulation from the ground. In wooden pole construction, the pole will be considered as one insulation.

l. Must be capable of being disconnected at the power plant, or of being divided into sections, so that in case of fire on the railway route the current may be shut off from the particular section to prevent its interfering with the work of the firemen. This also applies to feeders.

m. Must be safely protected against accidental contact where crossed by other conductors.

Ground Return Wires.—*n.* For the diminution of electrolytic corrosion of underground metal-work, ground return wires must be so arranged that the difference of potential between the grounded dynamo terminal and any point on the return circuit will not exceed twenty-five volts.

Transformers.—*a.* Must not be placed inside of any building. excepting central stations, unless by special permission of the inspection department having jurisdiction.

b. Must not be attached to the outside walls of buildings, unless separated therefrom by substantial supports.

Grounding Low-potential Circuits.—The grounding of low-potential circuits under the following regulations is only allowed when such circuits are so arranged that under normal conditions of service there will be no passage of current over the ground wire.

Direct-current Three-wire Systems.—*a.* Neutral wire may be grounded, and when grounded the following rules must be complied with:

1. Must be grounded at the central station on a metal plate buried in coke beneath permanent-moisture level, and also through all available underground water- and gas-pipe systems.

2. In underground systems the neutral wire must also be grounded at each distributing-box through the box.

3. In overhead systems the neutral wire must be grounded every 500 feet, as provided in §§ *c*, *e*, *f*, and *g*.

Alternating-current Secondary Systems.—*b.* The neutral points of transformers or the neutral wire of distributing systems may be grounded, and when grounded the following rules must be complied with:

1. Transformers feeding two-wire systems must be grounded at the centre of the secondary coils, as provided in §§ *d*, *e*, *f*, and *g*.

2. Transformers feeding systems with a neutral wire must have the neutral wire grounded as provided in §§ *d*, *e*, *f*, and *g* at the transformer, and at least every 250 feet for overhead systems and every 500 feet for underground systems.

Ground Connections.—*c.* The ground wire in direct-current three-wire systems must not at central stations be smaller than the neutral wire, and smaller than No. 6 B. & S. gauge elsewhere.

d. The ground wire in alternating-current systems must never be less than No. 6 B. & S. gauge, and must always have a

carrying capacity equal to that of the secondary lead of the transformer, or the combined leads where transformers are connected in parallel.

e. The ground wire must be kept outside of buildings, but may be directly attached to the building or pole. The wire must be carried as nearly in a straight line as possible, and kinks, coils, and sharp bends must be avoided.

f. The ground connections for central stations, transformer sub-stations, and banks of transformers must be made through metal plates buried in coke below permanent-moisture level, and connection should also be made to all available underground piping systems, including the lead sheaths of underground cables.

g. For individual transformers and building services, the ground connection may be made as in *F*, or may be made to water or other piping systems running into the buildings. This connection may be made by carrying the ground wire into the cellar and connecting on the street side of meters, main cocks, etc., but connection must never be made to any lead pipes which form part of gas services.

INSIDE WORK.

ALL SYSTEMS AND VOLTAGES.

GENERAL RULES.

14. Wires.—(For special cases, see Rules 18, 24, 35, 38, and 39.)

a. Must not be of smaller size than No. 14 B. & S. gauge, except as allowed under Rules 24, *v* and 45, *b*.

b. Tie wires must have an insulation equal to that of the conductors which they confine.

c. Must be so spliced or joined as to be both mechanically and electrically secure without solder. The joints must then be soldered to insure preservation, and covered with an insulation equal to that on the conductors.

Stranded wires must be soldered before being fastened under clamps or binding-screws, and when they have a conductivity greater than that of No. 10 B. & S. gauge copper wire, they must be soldered into lugs.

d. Must be separated from contact with walls, floors, timbers, or partitions through which they may pass by non-combustible,

non-absorptive, insulating tubes, such as glass or porcelain except as provided in Rule 24, *u*.

e. Must be kept free from contact with gas, water, or other metallic piping, or any other conductors or conducting material which they may cross, by some continuous and firmly fixed non-conductor, creating a separation of at least one inch. Deviations from this rule may sometimes be allowed by special permission.

f. Must be so placed, in wet places, that an air space will be left between conductors and pipes in crossing, and the former must be run in such a way that they cannot come in contact with the pipe accidentally. Wires should be run over rather than under pipes upon which moisture is likely to gather, or which by leaking might cause trouble on a circuit.

15. *Underground Conductors.—a*. Must be protected against moisture and mechanical injury where brought into a building and all combustible material must be kept removed from the immediate vicinity.

b. Must not be so arranged as to shunt the current through a building around any catch-box.

16. *Table of Carrying Capacity of Wires.—a*. The following table, showing the allowable carrying capacity of copper wires and cables of 98 per cent conductivity, according to the standard adopted by the American Institute of Electrical Engineers, must be followed in placing interior conductors.

For insulated aluminum wire the safe carrying capacity is 84 per cent of that given in the following tables for copper wire with the same kind of insulation.

The lower limit is specified for rubber-covered wires to prevent gradual deterioration of the high insulations by the heat of the wires, but not from fear of igniting the insulation. The question of drop is not taken into consideration in the tables.

The carrying capacity for No. 16 and No. 18 wire is given, but no smaller than No. 14 is to be used, except as allowed under Rules 24, *v* and 45, *b*.

There is a general agreement among those familiar with the effect of heat on rubber, that, if long life is desired, the temperature should not exceed 150° F.

In 1889, Mr. A. E. Kennelly made an elaborate series of careful experiments at the Edison Laboratory, to determine the temperature rise caused in wires under different conditions by currents of various strengths.

B. & S. Gauge.	Table A. Rubber-covered Wires. See Rule 41. Amperes.	Table B. Weather-proof Wires. See Rules 42 to 44. Amperes.	Circular Mils.
18	3	5	1,624
16	6	8	2,583
14	12	16	4,107
12	17	23	6,530
10	24	32	10,380
8	33	46	16,510
6	46	65	26,250
5	54	77	33,100
4	65	92	41,740
3	76	110	52,630
2	90	131	66,370
1	107	156	83,690
0	127	185	105,500
00	150	220	133,100
000	177	262	167,800
0000	210	312	211,600
Circular Mils.			
200,000	200	300	
300,000	270	400	
400,000	330	500	
500,000	390	590	
600,000	450	680	
700,000	500	760	
800,000	550	840	
900,000	600	920	
1,000,000	650	1,000	
1,100,000	690	1,080	
1,200,000	730	1,150	
1,300,000	770	1,220	
1,400,000	810	1,290	
1,500,000	850	1,360	
1,600,000	890	1,430	
1,700,000	930	1,490	
1,800,000	970	1,550	
1,900,000	1,010	1,610	
2,000,000	1,050	1,670	

The currents given in Table A are about 60 per cent of the currents which Mr. Kennelly found caused a rise of 75° F., or

a final temperature of about 150° F., assuming 75° F. as the average indoor temperature. This margin of 40 per cent is to allow for inevitable increase of current, such as that produced by the changing from one size lamp to those of a larger candle-power, the adding of more lamps to a circuit, the overloading of a motor, etc. The currents given in Table A cause a rise of temperature of about 29° F. above the surroundings, but varying somewhat with the size of the wire. It is well to remember in this connection that the heating effect increases about as the square of the current, i.e., if the current is doubled, for instance, the heating effect increases four times.

The limiting temperature for weather-proof insulation is about the same as for rubber, but a smaller factor of safety is allowable, as the covering on this class of wire is not greatly depended on for insulation, the insulation of the system being secured by the porcelain or glass supports to which the wire is attached. The currents in Table B, therefore, were obtained by taking 90 per cent of the currents which Mr. Kennelly found caused the wire to reach a temperature of 150° F., when the surrounding air was at 75° F. This allows a margin of only 10 per cent instead of the 40 per cent considered necessary in Table A.

It is interesting to note that, for any given size of wire, a current about three times as great as that given in Table A causes all ordinary insulations to begin to smoke.

Owing to the cooling effect of air-currents, the safe carrying capacity of outdoor conductors may be several times greater than the above, without causing any dangerous rise of temperature. As the conditions will vary so widely, and as such outdoor conductors are not at all liable to cause fire, no table has been made for them.

The following table shows, to the nearest one-hundredth of an ampere, the current consumed by incandescent lamps of various candle-powers, at the voltages in most common uses This table is figured on the basis of an efficiency of 3.6 watt. per candle-power for the 52-, 104-, and 110-volt lamps, and 4.0 watts per candle-power for the 220-volt lamps.

17 *Switches, Cut-outs, Circuit-breakers etc.*—(For construction requirements, see Rules 51, 52, and 53.)

a. Must, whenever called for, unless otherwise provided (for exceptions see Rules 8, *c* and 22, *c*), be so arranged that the cut-outs will protect, and the opening of the switches or

Voltage.	8 C.P.	10 C.P.	16 C.P.	20 C.P.	24 C.P.	32 C.P.	50 C.P.
52	.55	.69	1.11	1.38	1.66	2.22	3.46
104	.28	.35	.55	.69	.83	1.11	1.73
110	.26	.33	.52	.65	.78	1.05	1.64
220	.15	.18	.29	.36	.44	.58	.91

circuit-breakers will disconnect, all of the wires; that is, in a two-wire system the two wires, and in a three-wire system the three wires, must be protected by the cut-out and disconnected by the operation of the switch or circuit-breaker.

b. Must not be placed in the immediate vicinity of easily ignitable material or where exposed to inflammable gases or dust or to combustible flyings.

c. Must, when exposed to dampness, be either inclosed in a water-proof box or mounted on porcelain knobs.

CONSTANT-CURRENT SYSTEMS.

PRINCIPALLY SERIES ARC LIGHTING.

18. WIRES.—*a.* Must have an approved rubber insulating covering. (See Rule 41.)

b. Must be arranged to enter and leave the building through an *approved* double-contact service switch (see Rule 51, *b*), mounted in a non-combustible case, kept free from moisture, and easy of access to police or firemen.

c. Must always be in plain sight, and never incased, except when *required* by the inspection department having jurisdiction.

d. Must be supported on glass or porcelain insulators which separate the wire at least one inch from the surface wired over, and must be kept *rigidly* at least eight inches from each other, except within the structure of lamps, on hanger-boards, or in cut-out boxes or like places, where a smaller distance is necessary.

e. Must, on side walls, be protected from mechanical injury by a substantial boxing, retaining an air space of one inch around the conductors, closed at the top (the wires passing through bushed holes), and extending not less than seven feet from the floor. When crossing floor-timbers in cellars or rooms,

where they might be exposed to injury, wires must be attached by their insulating supports to the under side of a wooden strip, not less than one-half of an inch in thickness.

19. Series Arc Lamps. — (For construction requirements, see Rule 57.)

a. Must be carefully isolated from inflammable material.

b. Must be provided at all times with a glass globe, surrounding the arc and securely fastened upon a closed base. Broken or cracked globes must not be used.

c. Must be provided with a wire netting (having a mesh not exceeding one and one-fourth inches) around the globe, and an *approved* spark-arrester (see Rule 58), when readily inflammable material is in the vicinity of the lamps, to prevent the escape of sparks of melted copper or carbon. It is recommended that plain carbons, not copper-plated, be used for lamps in such places.

d. Where hanger-boards (see Rule 56) are not used, lamps must be hung from insulating supports other than their conductors.

20. Incandescent Lamps in Series Circuits.—*a.* Must have the conductors installed as required in Rule 18, and each lamp must be provided with an automatic cut-out.

b. Must have each lamp suspended from a hanger-board by means of a rigid tube.

c. No electromagnetic device for switches and no multiple-series or series-multiple system of lighting will be approved.

d. Must not, under any circumstances, be attached to gas fixtures.

CONSTANT-POTENTIAL SYSTEMS.

GENERAL RULES—ALL VOLTAGES.

21. Automatic Cut-outs.—*Fuses and Circuit-breakers.*—(For construction requirements, see Rules 52 and 53.) (See also Rule 17.)

a. Must be placed on all service wires, either overhead or underground, as near as possible to the point where they enter the building, and inside the walls, and arranged to cut off the entire current from the building.

b. Must be placed at every point where a change is made

in the size of wire, unless the cut-out in the larger wire will protect the smaller. (See Rule 16.)

c. Must be in plain sight, or inclosed in an *approved* box (see Rule 54), and readily accessible. They must not be placed in the canopies or shells of fixtures.

d. Must be so placed that no set of incandescent lamps requiring more than 660 watts, whether grouped on one fixture or on several fixtures or pendants, will be dependent upon one cut-out. Special permission may be given in writing by the inspection department having jurisdiction for departure from this rule in the case of large chandeliers, stage borders, and illuminated signs.

e. The rated capacity of fuses must not exceed the allowable carrying capacity of the wire as given in Rule 16. Circuit-breakers must not be set more than 30 per cent above the allowable carrying capacity of the wire unless a fusible cutout is also installed in the circuit.

22. SWITCHES.—*a.* Must be placed on all service wires, either overhead or underground, in a readily accessible place, as near as possible to the point where the wires enter the building and arrange to cut off the entire circuit.

b. Must always be placed in dry, accessible places, and should be grouped as far as possible. Knife switches must be so placed that gravity will tend to open rather than to close them.

c. Must not be single-pole when the circuits which they control supply devices which require over 660 watts of energy, or when the difference of potential is over 300 volts.

d. Where flush switches are used, whether with conduit systems or not, they must be inclosed in boxes constructed of or lined with fire-resisting material. No push-buttons for bells, gas-lighting circuits, or the like shall be placed in the same wall plate with switches controlling electric-light or power wiring.

e. Where possible, at all switch or fixture outlets, a seven-eighths-inch block must be fastened between studs or floor-timbers, flush with the back of lathing, to hold tubes and to support switches or fixtures. When this cannot be done, wooden base blocks not less than three-fourths of an inch in thickness, securely screwed to lathing, must be provided for switches, and also for fixtures which are not attached to gas-pipes or conduit tubing.

23. Electric Heaters.—*a.* Must, if stationary, be placed in a safe situation, isolated from inflammable materials, and must be treated as sources of heat.

b. Must each have a cut-out and an *indicating* switch. (See Rule 17, *a.*)

c. The attachments of feed wires to the heaters must be in plain sight, easily accessible, and protected from interference, accidental or otherwise.

d. The flexible conductors for portable apparatus, such as irons, etc., must have an *approved* insulating covering. (See Rule 45, *g.*)

e. Must each be provided with a name-plate, giving the maker's name and the normal capacity in volts and amperes.

LOW-POTENTIAL SYSTEMS, 550 VOLTS OR LESS.

Any circuit attached to any machine or combination of machines which develops a difference of potential between any two wires of over 10 *volts and less than* 550 *volts shall be considered as a low-potential circuit and as coming under this class, unless an approved transforming device is used which cuts the difference of potential down to* 10 *volts or less. The potential difference on the primary circuit must not exceed* 3500 *volts.*

Before pressure is raised above 300 *volts on any previously existing system of wiring, the whole must be strictly brought up to all of the requirements of the rules at date.*

24. Wires.

GENERAL RULES.

(See also Rules 14, 15, and 16.)

a. Must be so arranged that under no circumstances will there be a difference of potential of over 300 *volts between any bare metal parts in any distributing switch or cut-out cabinet or equivalent centre of distribution.*

b. Must not be laid in plaster, cement, or similar finish, and must never be fastened with staples.

c. Must not be fished for any great distance, and only in places where the inspector can satisfy himself that the rules have been complied with.

d. Twin wires must never be used, except in conduits or where flexible conductors are necessary.

f. When run immediately under roofs or in proximity to water tanks or pipes will be considered as exposed to moisture.

SPECIAL RULES FOR OPEN WORK.

IN DRY PLACES.—*g.* Must have an *approved* rubber or "slow-burning weather-proof" insulation. (See Rules 41 and 42.)

h. Must be rigidly supported on non-combustible, non-absorptive insulators, which will separate the wires from each other and from the surface wired over in accordance with the following table:

Voltage.	Distance from Surface.	Distance between Wires.
0 to 300	½ inch	2½ inch
300 to 550	1 "	4 "

Rigid supporting requires, under ordinary conditions, where wiring along flat surfaces, supports at least every four and one-half feet. If the wires are liable to be disturbed, the distance between supports should be shortened. In buildings of mill construction, mains of No. 8 B. & S. gauge wire or over, where not liable to be disturbed, may be separated about four inches and run from timber to timber, not breaking around, and may be supported at each timber only.

This rule will not be interpreted to forbid the placing of the neutral of an Edison three-wire system in the centre of a three-wire cleat where the difference of potential between the outside wires is not over 300 volts, provided the outside wires are separated two and one-half inches.

In damp places, such as breweries, sugar-houses, packing-houses, stables, dye-houses, paper-mills, pulp-mills, or other buildings especially liable to moisture or to acid or other fumes which might injure the wires or their insulation:

i. Must have an *approved* rubber insulating covering. (See Rule 41.)

j. Must be rigidly supported on non-combustible, non-absorptive insulators which separate the wire at least one inch from the surface wired over, and must be kept apart at least two and one-half inches for voltages up to 300, and four inches for higher voltages.

k. Must have no joints or splices.

FOR MOULDING WORK.—*l.* Must have an *approved* rubber insulating covering. (See Rule 41.)

m. Must never be placed in moulding in concealed or damp places, or where the difference of potential between any two wires in the same moulding is over 300 volts.

FOR CONDUIT WORK.—*n.* Must have an *approved* rubber insulating covering. (See Rule 47.)

o. Must not be drawn in until all the mechanical work on the building has, as far as possible, been completed.

p. Must, for alternating-current systems, have the two or more wires of a circuit drawn into the same conduit.

FOR CONCEALED KNOB AND TUBE WORK.—*q.* Must have an *approved* rubber insulating covering. (See Rule 41.)

r. Must be rigidly supported on non-combustible, non-absorptive insulators which separate the wire at least one inch from the surface wired over. Must be kept at least ten inches apart, and, when possible, should be run singly on separate timbers or studdings. Must be separated from contact with the walls, floor-timbers, and partitions through which they may pass by non-combustible, non-absorptive insulating tubes, such as glass or porcelain.

s. When from the nature of the case it is impossible to place concealed wiring on non-combustible supports of glass or porcelain, an approved armored cable with single or twin conductors (see Rule 48) may be used, where the difference of potential between conductors is not over 300 volts, provided it is installed without joints between outlets, and that the cable armor properly enters all fittings and is rigidly secured in place; or, if the difference of potential between wires is not over 300 volts, and if the wires are not exposed to moisture, they may be fished on the loop system if separately incased throughout in approved flexible conduits.

t. Conduit used for mixed "concealed knob and tube" and "conduit" work must be continuous from outlet to outlet, and must comply throughout with rules for conduit work. (See Rules 24, *n* to 24, *p*, and 25.)

u. Must, at outlets for combination fixtures, be bushed with approved flexible insulating tubes, extending in continuous lengths from the last porcelain support to one inch beyond the outlet, except that an approved outlet insulator may be used. At outlets where there are no gas-pipes, either this class of construction or porcelain bushing tubes may be used.

v. Must have an *approved* rubber insulating covering (see Rule 46), and must not be smaller than No. 18 B. & S. gauge.

w. Supply conductors, and especially the splices to fixture wires, must be kept clear of the grounded part of gas-pipes, and where shells or outlet boxes are used, they must be made sufficiently large to allow the fulfilment of this requirement.

x. Must, when fixtures are wired outside, be so secured as not to be cut or abraded by the pressure of the fastenings or motion of the fixture.

25. Interior Conduits.—*a*. No conduit tube having an internal diameter of less than five-eighths of an inch shall be used. With lined conduit, this measurement is to be taken inside the metal tube.

b. Must be continuous from one junction box to another, or to fixtures, and the conduit tube must properly enter all fittings.

c. Must first be installed as a complete conduit system, without the conductors.

d. Must be equipped at every outlet with an approved outlet box or plate.

e. Metal conduits, where they enter the junction boxes, and at all other outlets, etc., must be supplied with a capping of approved material, fitted so as to protect the wire from abrasion.

f. The metal of the conduit must be permanently and effectually grounded.

26. Fixtures.—(See also Rules 22, *e*, and 24, *v* to 24, *x*.)—*a*. Must, when supported from the gas-piping or any grounded metal-work of a building, be insulated from such piping or metal-work by means of *approved* insulating joints (see Rule 59) placed as close as possible to the ceiling.

b. Must have all burrs, or fins, removed before the conductors are drawn into the fixtures.

c. Must be tested for "contacts" between conductors and fixtures, for "short circuits" and for ground connections, before they are connected to their supply conductors.

27. Sockets.—(For construction requirements, see Rule 55.)—*a*. In rooms where inflammable gases may exist, the incandescent lamp and the socket must be inclosed in a vapor-tight globe and supported on a pipe-hanger, wired with *approved* rubber-covered wire (see Rule 41) soldered directly to the circuit.

b. In damp or wet places, or over especially inflammable material, water-proof sockets must be used.

28. Flexible Cord.—*a.* Must have an *approved* insulation and covering. (See Rule 45, *c.*)

b. Must not be used where the difference of potential between the two wires is over 300 volts.

c. Must not be used as a support for clusters.

d. Must not be used except for pendants, portable lamps, or motors, and portable heating apparatus.

e. Must not be used in show windows.

f. Must be protected by insulating bushings where it enters the socket.

g. Must be so suspended that the entire weight of the socket and lamp will be borne by knots under the bushing in the socket and above the point where the cord comes through the ceiling block or rosette, in order that the strain may be taken from the joints and binding screws.

29. Arc Lights on Constant-potential Circuits.—*a.* Must have a cut-out (see Rule 17, *a*) for each lamp or each series of lamps.

b. All resistances or regulators must be inclosed in non-combustible material and must be treated as sources of heat. Incandescent lamps must not be used for this purpose.

c. Must be supplied with globes and protected by spark-arresters and wire netting around the globe, as in the case of series arc lamps. (See Rules 19 and 58.)

30. Economy Coils.—*a.* Economy and compensator coils for arc lamps must be mounted on non-combustible, non-absorptive insulating supports, such as glass or porcelain, allowing an air space of at least one inch between frame and support, and must, in general, be treated as sources of heat.

Soldering Fluid.—The following formula for soldering fluid for electric wires is recommended by the National Board of Fire Underwriters, in the "National Electrical Code":

Saturated solution of zinc chloride.	5 parts.
Alcohol.	4 parts.
Glycerine.	1 part.

Heating.—During the progress of this part of the work, the superintendent must pay strict attention to the running of pipes, location of valves, registers, radiators, etc.

If the system to be used is a simple hot-air system, he must see that all hot-air pipes are run as direct as possible to their respective outlets; there should be as few bends or angles as possible, and where a turn is made it should be done with an easy elbow and not with a square turn, as is often done.

He should see that the pipes are so run that there will be no woodwork close enough to them to cause danger from fire.

LOCATION OF REGISTERS.—The bottom register when placed in the wall of a room should be just high enough to clear the base, and the one at the ceiling just low enough to clear the cornice or border.

A more evenly heated room will be the result if the registers are placed in an outside wall than if placed in an inside wall, but this point is often ignored, as it requires more pipe, and the hot-air pipes in the wall have to be covered to prevent the escape of the heat.

He should see that the outlets of all hot-air or vent pipes are so arranged that the register plate can be fastened on without any trouble, and he should also see that the flange of the outlet projects just far enough to receive the plaster; workmen are usually very careless regarding this point and often leave the flange project too far, and the plasterer will work to it and thus make a crooked job of plastering.

STEAM OR HOT-WATER SYSTEMS.—When either of the aboves systems are used the superintendent must see that the pipes are run and given the proper fall from the radiators, to carry back to the boiler the condensed steam, or the cold water. In a one-pipe system, which is the simplest form of steam heating, there is but one line of pipe from the boiler to the radiators and this pipe must be given fall enough to carry back the condensed steam. In the two-pipe system there are two lines of pipes, and the steam or hot water makes a circuit through the radiator and back to the boiler in the return pipe.

The superintendent must see that valves are placed where called for, or shown on the drawings, and he should see that all valves used are the full capacity or of equal area of the pipe which they control.

In taking branch lines from the main they should always be taken from the top of the pipe so that all drippings or condensation can run back without trapping the pipe.

All radiator connections, and all T or branch outlets, should

be plugged or capped as soon as put in place to prevent any dirt from getting in the pipe and possibly damaging the valves.

In running all pipes care must be taken to provide for expansion and contraction, and suitable provision made so there will be no danger of breaking a pipe or connection.

After the piping is all in place it should be tested before being covered up; this should be done by filling the pipes full of water and applying pressure with a force-pump to 100 or 150 pounds, then if possible a steam test should be made before covering the pipes.

All hot-water or steam pipes should be kept clear of all woodwork or other combustible material by about 4 inches.

PRESSURE OF SYSTEMS.—The high-pressure system is applied with steam at any pressure over 10 pounds.

The low-pressure system is operated with a pressure of from 2 to 5 pounds.

LOCATION OF RADIATORS.—Radiators should always be placed at outside walls, and near or under the window, so as to counteract the entrance of the cold air at the window. This will give a more even temperature in the room than if the radiator were located at the other side of the room.

In piping for a hot-water system all bends and angles should be made as easy as possible so as to prevent friction.

DATA FOR HOT-WATER HEATING.

TABLE OF RATIOS.

Dwellings.	One Square Foot of Radiating Surface will Heat
Living-rooms, one side exposed	30 cubic feet.
" , two sides exposed	28 " "
" , three sides exposed	28 " "
Sleeping-room	From 30 to 40 " "
Hall-room	" 20 " 30 " "
Bath-room	" 20 " 30 " "
Public Buildings.	
School-rooms	" 30 " 50 " "
Offices	" 30 " 50 " "
Factories	" 50 " 70 " "
Stores	" 50 " 70 " "
Auditoriums	" 80 " 100 " "
Churches	" 80 " 100 " "

The above ratios are for direct heating and an average temperature of 168° Fahr. in the water.

If indirect radiators are used, allow not less than 50 per cent more surface and for direct-indirect 25 per cent more.

Due care must be exercised to provide for any special conditions, such as exposure of buildings, material of construction, location and length and size of mains governing plant under consideration.

Allowances should also be made for loose construction of doors and windows, which admit large volumes of cold air, and provide for outside doors which are used frequently and open directly into the room.

In estimating the radiating surface, it should be borne in mind that a large surface at a comparatively low temperature gives a much pleasanter atmosphere than a small surface at a high temperature.

LIST OF SIZES OF HOT-WATER MAINS.

Radiation.		
75	square feet	1 inch pipe.
75 to 125	" "	1¼ " "
125 " 175	" "	1½ " "
175 " 300	" "	2 " "
300 " 475	" "	2½ " "
475 " 700	" "	3 " "
700 " 950	" "	3½ " "
950 " 1200	" "	4 " "
1200 " 1575	" "	4½ " "
1575 " 1975	" "	5 " "
1975 " 2375	" "	5½ " "
2375 " 2850	" "	6 " "

Inch Mains.		Branches.
1	will supply	two ¾ in.
1¼	" "	" 1 "
1½	" "	" 1¼ "
2	" "	" 1½ "
2½	" "	" 1½ " and one 1¼ in., or one 2 in. and one 1½ in.
3	" "	one 2½ " and one 1 in., or two 2 in. and one 1½ in.
3½	" "	two 2½ " or one 3 in. and one 2 in., or three 2 in.
4	" "	one 3½ " and one 2½ in., or two 3 in., or four 2 in.
4½	" "	" 3½ " and one 3 in., or one 4 in. and one 2½ in.
5	" "	" 4 " and one 3 in., or one 4½ in. and one 2½ in.
6	" "	two 4 " and one 3 in., or four 3 in. or ten 2 in.
7	" "	one 6 " and one 4 in., or two 4 in. and one 2 in.
8	" "	two 6 " and one 5 in., or five 4 in. and two 2 in.

APPROXIMATE NUMBER OF CUBIC FEET OF AIR ONE SQUARE FOOT OF RADIATION WILL HEAT. (NASON.)

One Square Foot of Radiating Surface will Heat with	In Dwellings, Schoolrooms, Offices, etc. Cubic Feet.	In Halls, Stores, Lofts, Factories, etc. Cubic Feet.	In Churches, Large Auditoriums, etc. Cubic Feet.
Direct-steam radiation	60 to 80	75 to 100	150 to 200
Indirect-steam radiation	40 to 50	50 to 70	100 to 140
High temperature, direct hot-water radiation	50 to 70	65 to 90	130 to 180
Low temperature, direct hot-water radiation	30 to 50	35 to 65	70 to 130
High temperature, indirect hot-water radiation	30 to 60	35 to 75	70 to 150
Low temperature, indirect hot-water radiation	20 to 40	25 to 50	50 to 100

The above proportions will give a temperature in the buildings described of 70° Fahr., the thermometer being at zero in the outside atmosphere.

While there is no iron-clad rule for computing the proper amount of radiation for heating buildings owing to the variable conditions that enter into the calculation, the above table will prove valuable if allowances are made for extreme cases.

It is well to remember that small rooms, rooms with large window surfaces or exposed sides, and rooms with exceptionally thick walls or fire-proof tiling require more radiating surface in proportion to space than is ordinarily needed. Frame buildings require more radiation than stone, and stone more than brick.

The following rules regarding heating by steam are given by Babcock & Wilcox:

Heating by Steam.—In heating buildings by steam, the amount of boiler and heating pipes depends largely on the kind of building and its location. Wooden buildings require more than stone, and stone more than brick. Iron fronts require still more, and glass in windows demands twenty times as much heat as the same surface in brick walls. Also if the heating be done by indirect radiation from 50 to 100 per cent more surface will be required than when direct radiation is used. No rules can be given which will not require a liberal application of "the coefficient of common sense."

Radiating surface may be calculated by the rule: *Add together the square feet of glass in the windows, the number of cubic feet of air required to be changed per minute, and one-twentieth the*

surface of external wall and roof; multiply this sum by the difference between the required temperature of the room and that of the external air at its lowest point and divide the product by the difference in temperature between the steam in the pipes and the required temperature of the room. The quotient is the required radiating surface in square feet. Each square foot of radiating surface may be depended upon in average practice to give out three heat-units per hour for each degree of difference in temperature between the steam inside and the air outside, the range under different conditions being about 50 per cent above or below that figure. In *indirect* heating the efficiency of the radiating surface will increase, and the temperature of the air will diminish, when the quantity of the air caused to pass through the coil increases. Thus one square foot radiating surface, with steam at 212°, has been found to heat 100 cubic feet of air per hour from zero to 150°, or 300 cubic feet from zero to 100° in the same time.

The best results are attained by using indirect radiation to supply the necessary ventilation, and direct radiation for the balance of the heat. The best place for a radiator in a room is beneath a window. Heated air cannot be made to enter a room unless means are provided for permitting an equal amount to escape. The best place for such exit openings is near the floor.

Small pipes are more effective than large. When the diameter is doubled, 20 per cent additional surface should be allowed, and for three times the diameter 30 per cent additional is required. For indirect radiation that surface is most efficient which secures the most intimate contact of the current of air with the heated surface. Rooms on windward side of house require more radiating surface than those on sheltered side.

Where the condensed water is returned to the boiler, or where low pressure of steam is used, the diameter of mains leading from the boiler to the radiating surface should be equal, in inches, to *one-tenth the square root of the radiating surface, mains included,* in square feet. Thus a 1-inch pipe will supply 100 square feet of surface, itself included. Return pipes should be at least ¾ inch in diameter, and never less than one-half the diameter of the main—longer returns requiring larger pipes. A thorough drainage of steam-pipes will effectually prevent all cracking and pounding noises therein.

The amount of air required for ventilation is from 4 to 16 cubic feet per minute for each person, the larger amount being for prisons and hospitals. From $\frac{1}{2}$ to 1 cubic foot per minute should be allowed for each lamp or gas-burner employed.

One square foot of boiler surface will supply from 7 to 10 square feet of radiating surface, depending upon the size of boiler and the efficiency of its surface, as well as that of the radiating surface. Small boilers for house use should be much larger proportionately than large plants. Each horse-power of boiler will supply from 240 to 360 feet of 1-inch steam-pipe, or from 80 to 120 square feet of radiating surface.

Cubic feet of space has little to do with amount of steam or surface required, but is a convenient factor for rough calculations. Under ordinary conditions one horse-power will heat, approximately, in

Brick dwellings, in blocks, as in cities. . .	15,000 to 20,000 cu. ft.
Brick stores, in blocks.	10,000 to 15,000 cu. ft.
Brick dwellings, exposed all round.	10,000 to 15,000 cu. ft.
Brick mills, shops, factories, etc.	7,000 to 10,000 cu. ft.
Wooden dwellings, exposed	7,000 to 10,000 cu. ft.
Foundries and wooden shops.	6,000 to 10,000 cu. ft.
Exhibition buildings, largely glass, etc.	4,000 to 15,000 cu. ft.

The system of heating mills and manufactories by means of pipes placed overhead is being largely adopted, and is recommended by the Boston Manufacturers' Mutual Fire Insurance Company, in preference to radiators near the floor, particularly for rooms in which there are shafting and belting to circulate the air.

In heating buildings care should be taken to supply the necessary moisture to keep the air from becoming "dry" and uncomfortable. The capacity of air for moisture rises rapidly as it is heated, it being four times as great at 72° as at 32°. For comfort, air should be kept at about "50 per cent saturated." This would require one pound of vapor to be added to each 2,500 cubic feet heated from 32° to 70°.

A much-needed attachment has recently been introduced, which acts automatically upon the steam-valves of the radiators, or upon the hot-air registers and ventilators, and maintains the temperature in a room to within one-half a degree of any standard desired.

A "separator" acting by centrifugal force has been recently tested, and is very efficient, in trapping out all the water entrained in steam. It will be found valuable, particularly where the steam has to be carried a long distance from the boiler, and for the purpose of preventing "hammering" of water in the pipes.

RESISTANCE TO FLOW BY BENDS, VALVES, ETC.—Mr. Briggs states in "Warming Buildings by Steam," that the resistance at the entrance to a pipe consists of two parts, namely, the head, $\frac{v^2}{2g}$, which is necessary to create the velocity of flow and the head, $0.505\frac{v^2}{2g}$, which overcomes the resistance to entrance offered by the mouth of the pipe. The total loss of head at entrance then equals the sum of these, or $1.505\frac{v^2}{2g}$, in which v = velocity of flow of steam in the pipe, in feet per second, and g = acceleration due to gravity, or 32.2.

The Babcock & Wilcox Company state in "Steam" that the resistance at the opening and that at a globe valve are each about the same as that caused by an additional length of straight pipe, as computed by the formula

$$\text{Additional length of pipe} = \frac{114 \times \text{diameter of pipe}}{1 + (3.6 \div \text{diameter})},$$

from which has been computed the following table:

Diameter in inches.........	2	2½	3	3½	4	5	6	7
Additional length, feet.....	7	10	13	16	20	28	36	44
Diameter in inches.........	8	10	12	15	18	20	22	24
Additional length, feet.....	53	70	88	115	143	162	181	200

The resistance to flow at a right-angled elbow is about equal to ⅔ that of a globe valve.

The above values are to be considered as being only approximations to the truth.

Example.—Find the discharge from a steam-pipe when the given length = 120 feet and the diameter = 8 inches, the pipe containing 6 right-angled elbows and two globe valves, the pressure at the two ends being respectively 105 and 103 pounds per square inch gauge.

The resistance to entrance, from the above table, for 8-inch pipe $=53$ feet; the resistance of 6 elbows $=6\times 53\times \frac{2}{3}=212$ feet; the resistance of two globe valves $=2\times 53=106$ feet; making a total resistance $=53+212+106=371$ feet of additional length of pipe. Therefore the steam would encounter the same resistance flowing through a straight 8-inch pipe whose length equals $120+371$, or 491 feet, as it would in flowing through the given pipe with its various resistances.

Then in the formula

$$W=c\sqrt{\frac{w(p-p_2)d^5}{L}},$$

$L=491$ feet; $p=105$ pounds per square inch; $p_2=103$ pounds per square inch; $d=8$ inches; c, for an 8-inch pipe, $=60.7$; and w, from table of Prôperties of Saturated Steam, $=0.27$.

Substituting in formula we get

$$W=60.7\sqrt{\frac{0.27(105-103)8^5}{491}}=364.$$

The pipe, then, under the stated conditions, would discharge approximately 364 pounds of steam per minute, or 21,800 pounds per hour; which, on the basis of 30 pounds per horse-power hour, would have a capacity of 728 boiler horse-powers. Since one pound of steam at 104 pounds gauge has a volume of 3.7 cubic feet, the pipe would discharge 1,350 cubic feet per minute, or 81,000 cubic feet per hour.

Non-conducting Coverings for Steam-pipes.—A bare pipe carrying steam, and made of iron, steel, or other conducting material, loses heat by convection to the surrounding air and by radiation to the surrounding objects, both of which cause a loss of steam by condensation.

This loss is lessened in practice by covering the outer surface of the steam-pipe with a material that will offer a greater resistance to the flow of heat than that offered by the material of the pipe.

A good material for this purpose should not suffer serious deterioration from the heat or vibration to which it would be subjected in practice; and in all cases where damage from fire might result, it should never consist of combustible matter. Under the conditions of practice, especially in places where it

may become damp, a good pipe covering should consist of materials that will not rapidly deteriorate, and should contain nothing that will seriously corrode the pipe.

Since air does not take up heat by radiation, but receives heat by contact with a hot body only, it would appear that the greater the porosity of a material—that is, the greater the percentage of volume of finely divided air it contains—the greater will be its non-conducting qualities. This is noticeably the case in the commercial pipe coverings that consist substantially of the same materials, when these materials contain different percentages of still air. In every case the more porous the material, other things being equal, the greater will be its non-conducting properties.

The following table contains averages made up from results obtained by a number of carefully conducted tests, and represent approximately what may be expected when these materials are properly applied as steam-pipe coverings in practice. The table gives the quantity of heat transmitted through covered steam-pipes, when that transmitted through a naked pipe is taken as 100, the covering, except where otherwise indicated, being one inch thick.

Kind of Covering.	Relative Amount of Heat Transmitted.
Naked pipe	100
Hair-felt, asbestos lined and canvas covered	16 to 18
Wool felt, " " " " "	20 " 22
Two layers of asbestos paper	70 " 80
Four " " " "	45 " 55
Asbestos mixed with some plaster of Paris	28 " 34
Magnesia mixed with a little asbestos fibre, canvas covered	18 " 20
Best mineral wool, lined and canvas covered	18 " 20
Pipe painted with black asphaltum	about 105
" " " white glossy paint	" 95

For coverings having values less than 25 in the above table, the values for thicknesses of covering of $1\frac{1}{2}$ and 2 inches (those in the table being for 1 inch, as noted) may be approximately obtained by multiplying respectively by 0.78 and 0.58. Thus a pipe covered with magnesia and canvas covered would transmit an amount, if $1\frac{1}{2}$ inches thick, $=(18 \text{ to } 20)\times 0.78 = 14 \text{ to } 15.5$; and if 2 inches thick an amount $=(18 \text{ to } 20)\times 0.58 = 10.5 \text{ to } 11.5$,

that transmitted by a similar bare pipe being 100 in the same length of time.

The following table gives the result of tests made by G. B. Dunford, of Hamilton, Ont., of various materials in regard to their quality as a non-conductor of heat.

Combination of asbestos, hair-felt, air space, and wood	100	per	cent.
Asbestos and hair-felt chopped and mixed with lime putty	87	"	"
A plastic cement manufactured by parties at Troy, N. Y., with ½ inch hair-felt outside	86.6	"	"
Paper pulp mixed with lime putty, 1 inch, covered with sheeting of wood pulp	85	"	"
Mineral wool cased with wood	81	"	"
Mineral wool cased with sheet iron	79	"	"
Charcoal	60	"	"
Sawdust	41	"	"
Loam and chopped straw sealed with wood	32	"	"
Asbestos	29	"	"
Coal ashes	24	"	"
Air space	20	"	"
Fire-brick	15	"	"
Red brick	12	"	"
Sand	9.3	"	"

Steam.—Under the ordinary atmospheric pressure of 14.7 pounds per square inch, water boils at 212° F., passing off as steam, the temperature at which it boils varying with a variation in the pressure.

Dry Steam is steam not containing any free moisture. It may be either saturated or superheated.

Wet Steam is steam containing free moisture in the form of spray or mist, and has the same temperature as dry saturated steam of the same pressure.

Saturated Steam is steam in its normal state, that is, steam whose temperature is that due its pressure; by which is meant steam at the same temperature as that of the water from which it was generated and upon which it rests.

Superheated Steam is steam at a temperature above that due to its pressure.

A British Thermal Unit is the quantity of heat required

to raise one pound of water at 39°.1 F. through one degree of temperature.

THE TOTAL HEAT OF THE WATER is the number of British thermal units needed to raise one pound of water from 32° F. to the boiling-point under the given pressure.

THE LATENT HEAT OF STEAM is the number of British thermal units required to convert one pound of water, at the boiling-point, into steam of the same temperature.

THE TOTAL HEAT OF SATURATED STEAM is the number of heat-units required to raise a pound of water from 32° F. to the boiling-point, at the given pressure, plus the number required to evaporate the water at that temperature.

THE SPECIFIC HEAT OF STEAM is the quantity of heat required to raise the temperature of one pound of steam through one degree of temperature. In British units and near the saturation temperature it equals, at constant pressure, 0.48.

THE SPECIFIC GRAVITY OF STEAM at any temperature and pressure, as compared with air of same temperature and pressure, is approximately 0.622. One cubic inch of water evaporated into steam at 212° F. becomes 1646 cubic inches, that is, nearly 1 cubic foot.

Water in contact with saturated steam has the same temperature as the steam itself. Water introduced into superheated steam will be vaporized until the steam becomes saturated and its temperature becomes that due its pressure. Cold water, or water at a lower temperature than that of the steam, introduced into saturated steam will condense some of it, thus lowering both the temperature and pressure of the rest until the temperature again equals that due its pressure.

USEFUL RULES AND INFORMATION.—*Steam.*—A cubic inch of water evaporated under ordinary atmospheric pressure is converted into 1 cubic *foot* of steam (approximately).

The specific gravity of steam (at atmospheric pressure) is 0.411 that of air at 34° Fahr., and 0.0006 that of water at the same temperature.

27,222 cubic feet of steam weigh 1 pound; 13,817 cubic feet of air weigh 1 pound.

Locomotives average a consumption of 3,000 gallons of water per 100 miles run.

The best-designed boilers, well set, with good draft and skilful firing, will evaporate from 7 to 10 pounds of water per pound of first-class coal.

In calculating horse-power of tubular or flue boilers, consider 15 square feet of heating surface equivalent to one *nominal* horse-power.

On 1 square foot of grate can be burned on an average from 10 to 12 pounds of hard coal, or 18 to 20 pounds of soft coal, per hour, with natural draft. With forced draft nearly double these amounts can be burned.

Steam-engines, in economy, vary from 14 to 60 pounds of feed-water and from 1½ to 7 pounds of coal per hour per indicated horse-power. See table below for duty of high-grade engines.

Condensing-engines require from 20 to 30 gallons of water, at an average low temperature, to condense the steam represented by every gallon of water evaporated in the boilers supplying engines—approximately for most engines, we say, from 1 to 1½ gallons condensing water per minute per indicated horse-power.

Surface condensers should have about 2 square feet of tube (cooling) surface per horse-power for a compound steam-engine. Ordinary engines will require more surface according to their economy in the use of steam. It is absolutely necessary to place air-pumps below condensers to get satisfactory results.

Ratio of Vacuum to Temperature (Fahrenheit) of Feed-water.

00 inches vacuum	212°
11 " "	190°
18 " "	170°
22½ " "	150°
25 * " "	135°
27½ " "	112°
28½ " "	92°
29 " "	72°
29½ " "	52°

Weight and Comparative Fuel Value of Wood.

1 cord air-dried hickory or hard maple weighs about 4500 pounds, and is equal to about 2000 pounds coal.

1 cord air-dried white oak weighs about 3850 pounds, and is equal to about 1715 pounds coal.

1 cord air-dried beech, red oak, or black oak weighs about 3250 pounds, and is equal to about 1450 pounds coal.

* Usually considered the standard point of efficiency—condenser and air-pump being well proportioned.

1 cord air-dried poplar (whitewood), chestnut, or elm weighs about 2350 pounds, and is equal to about 1050 pounds coal.

1 cord air-dried average pine weighs about 2000 pounds, and is equal to about 925 pounds coal.

From the above it is safe to assume that 2¼ pounds of dry wood is equal to 1 pound average quality of soft coal, and that the full value of the same *weight* of different woods is very nearly the same—that is, a pound of hickory is worth no more for fuel than a pound of pine, assuming both to be dry. It is important that the wood be dry, as each 10 per cent of water or moisture in wood will detract about 12 per cent from its value as fuel.

PIPE DATA.

Inside Diameter Nominal.	Internal Area in Inches.	Circumference of Pipe in Inches.	Length of Pipe in Feet per Sq. Ft. of Radiating Surface.	Number of Sq. Feet in 1 Lineal Foot of Pipe.	Contents in Gallons per Foot.	Weight in Pounds per Lineal Foot.	Number of Threads per Inch of Screw.
½	.3048	2.652	4.502	.221	.0102	½— 0.84	14
¾	.5333	3.299	3.637	.274	.0230	¾— 1.126	14
1	.8627	4.134	2.903	.344	.0408	1 — 1.670	11½
1¼	1.496	5.215	2.301	.434	.0638	1¼— 2.258	11½
1½	2.038	5.969	2.010	.497	.0918	1½— 2.694	11½
2	3.355	7.461	1.611	.621	.1632	2 — 3.667	11½
2½	4.783	9.032	1.328	.752	.2550	2½— 5.773	8
3	7.368	10.99	1.091	.916	.3673	3 — 7.547	8
3½	9.837	12.56	.955	1.044	.4998	3½— 9.055	8
4	12.730	14.13	.849	1.178	.6528	4 —10.728	8
4½	15.939	15.70	.765	1.309	.8263	4½—12.492	8
5	19.990	17.47	.629	1.656	1.0200	5 —14.564	8
6	28.889	20.81	.577	1.733	1.5500	6 —18.767	8

Duty of Steam-engines.—A well-known engineer of high authority gives the following comparative figures, showing the economy of high-grade steam-engines in actual practice:

Type of Engine.	Temperature of Feed-water.	Pounds of Water Evaporated per Pound of Cumberland Coal.	Pounds of Steam per I.H.P. Used per Hour.	Pounds of Cumberland Coal Used per I.H.P. per Hour.	Cost per I.H.P. per Hour, Supposing Coal at $6 per Ton.
Non-condensing.	210°	10.5	29.	2.75	$0.0073
Condensing.	100°	9.4	20.	2.12	0.0056
Compound jacketed.	100°	9.4	17.	1.81	0.0045
Triple-expansion jacketed.	100°	9.4	13.6	1.44	0.0036

The effect of a good condenser and air-pump should be to make available about 10 pounds more mean effective pressure with the same terminal pressure; or to give the same mean effective pressure with a correspondingly less terminal pressure. When the load on the engine requires 20 pounds M.E.P., the condenser does half the work; at 30 pounds, one-third of the work; at 40 pounds, one-fourth, and so on. It is safe to assume that practically the condenser will save from one-fourth to one-third of the fuel, and it can be applied to any engine, cut-off, or throttling where a sufficient supply of water is available.

DATA FOR STEAM HEATING.—Under ordinary conditions, one square foot of direct radiating surface will heat approximately in

Bathroom, living-room, with two or three exposures and large amount of glass.	40 cu. ft.
Living-room, one or two exposures, with large amount of glass	50 cu. ft.
Living-room, one exposure, amount of glass	60 cu. ft.
Sleeping-rooms	55 to 70 cu. ft.
Halls	50 to 70 cu. ft.
Schoolrooms	60 to 80 cu. ft.
Churches and auditoriums of large cubic contents and high ceilings	65 to 100 cu. ft.
Lofts, workshops, and factories	75 to 150 cu. ft.

If indirect radiators are used, allow not less than 50 per cent more surface than for direct, and for direct indirect, 25 per cent more.

In estimating the radiating surface make due allowance for exposure of building, material of construction, location, length and size of main location and capacity of boiler, also loose construction of doors and windows.

COMPARISON OF THERMOMETRIC SCALES.—To convert the degrees of Centigrade into those of Fahrenheit, multiply by 9 divide by 5, and add 32.

To convert degrees of Centigrade into those of Réaumur, multiply by 4 and divide by 5.

To convert degrees of Fahrenheit into those of Centigrade, deduct 32, multiply by 5, and divide by 9.

To convert degrees of Fahrenheit into those of Réaumur, deduct 32, divide by 9, and multiply by 4.

To convert degrees of Réaumur into those of Centigrade, multiply by 5 and divide by 4.

LIST OF SIZES OF STEAM MAINS.

Radiation.	One-pipe Work.	Two-pipe Work.
40 to 50 square feet	1 inch	¾ × ¾ inch
100 to 125 " "	1¼ "	1 × ¾ "
125 to 250 " "	1½ "	1¼ × 1 "
250 to 400 " "	2 "	1½ × 1¼ "
400 to 650 " "	2½ "	2 × 1½ "
650 to 900 " "	3 "	2½ × 2 "
900 to 1250 " "	3½ "	3 × 2½ "
1250 to 1600 " "	4 "	3½ × 3 "
1600 to 2050 " "	4½ "	4 × 3½ "
2050 to 2500 " "	5 "	4½ × 4 "
2500 to 3600 " "	6 "	5 × 4½ "
3600 to 5000 " "	7 "	6 × 5 "
5000 to 6500 " "	8 "	7 × 6 "
6500 to 8100 " "	9 "	8 × 6 "
8100 to 10000 " "	10 "	9 × 6 "

TABLE OF EXPANSION OF WROUGHT-IRON PIPE.

Temperature of the Air when the Pipe is Fitted.	Length of Pipe when Fitted.	Length of Pipe when Heated.					
		160 Degrees.		180 Degrees.		200 Degrees.	
Degrees Fahr.	Feet.	Feet.	In.	Feet.	In.	Feet.	In.
0	100	100	1.28	100	1.44	100	1.60
32	100	100	1.02	100	1.18	100	1.34
64	100	100	.77	100	.93	100	1.09

To convert degrees of Réaumur into those of Fahrenheit, multiply by 9, divide by 4, and add 32.

In De Lisle's thermometer, used in Russia, the graduation begins at boiling-point, which is marked zero, and the freezing-point is 150.

The following rules regarding the installation of heating apparatus are taken from the New York Building Code:

HEATING APPARATUS, DRYING-ROOMS, GAS- AND WATER-PIPES.

Sec. 84. *Heating-furnace sand Boilers.* — A brick-set boiler shall not be placed on any wood or combustible floor or beams. Wood or combustible floors and beams under and not less than three feet in front and one foot on the sides of all portable boilers

shall be protected by a suitable brick foundation of not less than two courses of brick well laid in mortar on sheet iron; the said sheet iron shall extend at least twenty-four inches outside of the foundation at the sides and front. Bearing lines of bricks, laid on the flat, with air-spaces between them, shall be placed on the foundation to support a cast-iron ash-pan of suitable thickness, on which the base of the boiler shall be placed, and shall have a flange, turned up in the front and on the sides, four inches high; said pan shall be in width not less than the base of the boiler and shall extend at least two feet in front of it. If a boiler is supported on a cast-iron base with a bottom of the required thickness for an ash-pan, and is placed on bearing lines of brick in the same manner as specified for an ash-pan, then an ash-pan shall be placed in front of the said base and shall not be required to extend under it. All lath-and-plaster and wood ceilings and beams over and to a distance of not less than four feet in front of all boilers shall be shielded with metal. The distance from the top of the boiler to said shield shall be not less than twelve inches. No combustible partition shall be within four feet of the sides and back and six feet from the front of any boiler, unless said partition shall be covered with metal to the height of at least three feet above the floor, and shall extend from the end or back of the boiler to at least five feet in front of it; then the distance shall be not less than two feet from the sides and five feet from the front of the boiler. All brick hot-air furnaces shall have two covers, with an air-space of at least four inches between them; the inner cover of the hot-air chamber shall be either a brick arch or two courses of brick laid on galvanized iron or tin, supported on iron bars; the outside cover, which is the top of the furnace, shall be made of brick or metal supported on iron bars, and so constructed as to be perfectly tight, and shall be not less than four inches below any combustible ceiling or floor-beams. The walls of the furnace shall be built hollow in the following manner: One inner and one outer wall, each four inches in thickness, properly bonded together with an air-space of not less than three inches between them. Furnaces must be built at least four inches from all woodwork. The cold-air boxes of all hot-air furnaces shall be made of metal, brick, or other incombustible material, for a distance of at least ten feet from the furnace. All portable hot-air furnaces shall be placed at least two feet from any wood or combustible partition or ceiling,

unless the partitions and ceilings are properly protected by a metal shield, when the distance shall be not less than one foot. Wood floors under all portable furnaces shall be protected by two courses of brickwork well laid in mortar on sheet iron. Said brickwork shall extend at least two feet beyond the furnace in front of the ash-pan.

Sec. 85. *Registers.*—Registers located over a brick furnace shall be supported by a brick shaft built up from the cover of the hot-air chamber; said shaft shall be lined with a metal pipe, and all wood beams shall be trimmed away not less than four inches from it. Where a register is placed on any woodwork in connection with a metal pipe or duct the end of the said pipe or duct shall be flanged over on the woodwork under it. All registers for hot-air furnaces placed in any woodwork or combustible floors shall have stone or iron borders firmly set in plaster of Paris or gauged mortar. All register-boxes shall be made of tin plate or galvanized iron with a flange on the top to fit the groove in the frame, the register to rest upon the same; there shall be an open space of two inches on all sides of the register-box, extending from the under side of the border to and through the ceiling below. The said opening shall be fitted with a tight tin or galvanized-iron casing, the upper end of which shall be turned under the frame. When a register-box is placed in the floor over a portable furnace, the open space on all sides of the register-box shall be not less than three inches. When only one register is connected with a furnace said register shall have no valve.

Sec. 86. *Drying-rooms.*—All walls, ceilings, and partitions inclosing drying-rooms, when not made of fire-proof material, shall be wire-lathed and plastered, or covered with metal, tile, or other hard incombustible material.

Sec. 87. *Ranges and Stoves.*—Where a kitchen range is placed from twelve to six inches from a wood stud-partition, the said partition shall be shielded with metal from the floor to the height of not less than three feet higher than the range; if the range is within six inches of the partition, then the studs shall be cut away and framed three feet higher and one foot wider than the range, and filled in to the face of the said stud-partition with brick or fire-proof blocks, and plastered thereon. All ranges on wood or combustible floors and beams that are not supported on legs and have ash-pans three inches or more above their base, shall be set on suitable brick foundations,

consisting of not less than two courses of brick well laid in mortar on sheet iron, except small ranges such as are used in apartment houses that have ash-pans three inches or more above their base, which shall be placed on at least one course of brick-work on sheet iron or cement. No range shall be placed against a furred wall. All lath-and-plaster or wood ceilings over all large ranges, and ranges in hotels and restaurants, shall be guarded by metal hoods placed at least nine inches below the ceiling. A ventilating-pipe connected with a hood over a range shall be at least nine inches from all lath-and-plaster or wood work, and shielded. If the pipe is less than nine inches from lath-and-plaster and wood work, then the pipe shall be covered with one inch of asbestos plaster on wire mesh. No ventilating-pipe connected with a hood over a range shall pass through any floor. Laundry-stoves on wood or combustible floors shall have a course of bricks, laid on metal, on the floor under and extended twenty-four inches on all sides of them. All stoves for heating purposes shall be properly supported on iron legs resting on the floor three feet from all lath-and-plaster or wood work; if the lath-and-plaster or wood work is properly protected by a metal shield, then the distance shall be not less than eighteen inches. A metal shield shall be placed under and twelve inches in front of the ash-pan of all stoves that are placed on wood floors. All low gas-stoves shall be placed on iron stands, or the burners shall be at least six inches above the base of the stoves, and metal guard-plates placed four inches below the burners, and all wood work under them shall be covered with metal.

PART V.

DRAWING. LAYING OUT WORK. MENSURATION. GEOMETRICAL MENSURATION. VARIOUS ENGINEERING FORMULAS.

Drawing.—To Bisect a Right Angle.—Take *a* as centre, Fig. 242, and any radius, and draw the arc *bc*. Now, with *bc* as centres and the same radius, draw the arcs bisecting *bc* in 1 and 2; draw lines from *a* through 1 and 2.

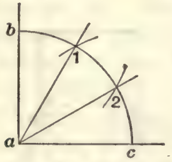


Fig. 242.

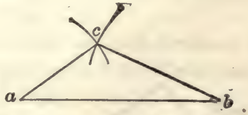


Fig. 243.

To Draw a Triangle when the Lengths of the Sides are Given.—Draw the length of one side, as *ab*, Fig. 243; then, with *a* as centre and the length of one of the other sides, describe an arc, as shown; then, with *b* as centre, describe an arc, as shown, using the length of the third side as radius; then connect this intersection and *ab*.

To Draw the Five-point Star (Fig. 245).—Draw the circumference and divide it into 5 equal parts, 1, 2, 3, etc.; connect 1 and 3, 3 and 5, 5 and 2, 2 and 4, and 4 and 1.

To Draw a Square when the Diagonal is Given.—Draw the diagonal, *ab*, Fig. 244; bisect it at *c* and draw the line *de* at right angles to *ab*; then with *ac* as radius and *c* as centre strike

a circle; then connect *ad*, *db*, *be*, and *ea*, which is the square required.

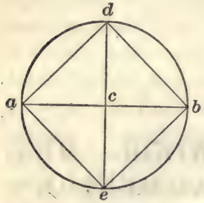


FIG. 244.

FIG. 245.

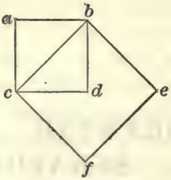


FIG. 246.

TO FIND A SQUARE TWICE THE AREA OF A GIVEN SQUARE.—Draw the given square, as *abcd*, Fig. 246; then, with the diagonal, *cb*, as one side, draw the square *cbef*, which will be twice the area of the first square.

TO DRAW A SQUARE HAVING THE AREA OF TWO GIVEN SQUARES.—Draw one side of each of the given squares so as to form a right angle, as *ab* and *bc*, Fig. 247; connect *ac*, and, with

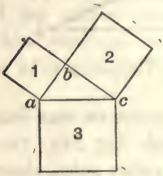


FIG. 247.

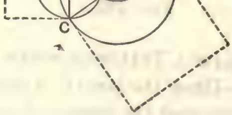


FIG. 248.

this line as one side, draw the square, 3, which is equal in area to 1 and 2.

The above rule applies to circles as well as squares; *ab* and *AC*, Fig. 248, represent the diameters of the smaller circles, and *CB* the diameter of a circle which is equal in area to the two small ones.

TO DRAW A TRIANGLE WHEN THE LENGTH OF ONE SIDE IS GIVEN.—Draw the side or base, as *ab*, Fig. 249; then, with *ab*

as radius, strike the arc *ac*; then with the same radius and *a* as centre, find point *d*; connect *ad* and *db*.

To Draw an Equilateral Triangle when the Perpendicular is Given.—Draw *ab* for the perpendicular, Fig. 250; then draw *cd* and *gh* at right angles to *ab*; then, with any radius and

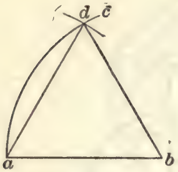


Fig. 249.

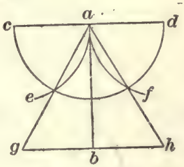


Fig. 250.

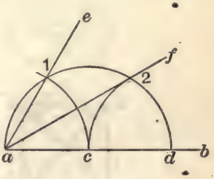


Fig. 251.

a as centre, draw the semicircle, *cefd*; then, with *c* as centre, find the point *e*; then, with *d* as centre, find the point *f*; then draw the line *ah* through the point *f*; then draw the line *ag* through *e*.

To Draw an Angle of 60° or 30°.—Draw the line *ab*, Fig. 251, and with any point on *ab*, as *c*, for centre and *ca* as radius, draw the arc *a*1, 2*d*. With *a* as centre and same radius find point 1; draw line from *a* through 1; $1ac = 60°$; with *d* as centre and same radius find point 2; $2ad = 30°$.

To Draw a Regular Polygon of any Number of Sides, when the Length of One Side is Given.—Take the length of the side for a base, as *ab*, Fig. 252; then with *ab* as radius and *a* as centre, draw the semicircle, *db*; then divide the semicircle into as many equal parts as there are sides to the polygon, in this case 7; then, as we have one side, *ab*, we skip the first division and connect *a* and 2; then from the centre of *a*2 and *ab* draw lines at right angles until they meet at *c*, which is the centre of the polygon.

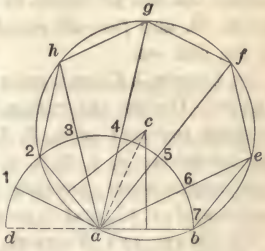


Fig. 252.

Then, with *c* at centre and *ca* as radius, draw the circle; then draw lines from *a* through points 3, 4, 5, and 6, striking the circ e at *h*, *g*, *f*, and *e*; now connect 2*h*, *hg*, *gf*, *fe*, and *eb*.

To Draw an Octagon.—When you have the distance from

one side to the other given, to draw the octagon, first draw a square, Fig. 253, of that size; then draw diagonal lines from each corner, as *aa*, *aa*; then take the distance from the centre to the outside, as shown by the dotted line, and measure the same distance from the centre on the lines, *aa*; then draw

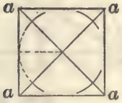


FIG. 253.

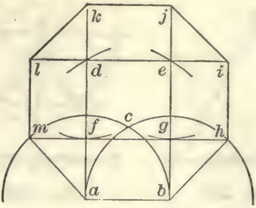


FIG. 254.

lines from this point at right angles to *aa* and you have the octagon.

TO DRAW AN OCTAGON WHEN THE SIDE OR BASE IS GIVEN.—Draw the line, *ab*, for the base, Fig. 254, and from *a* and *b* draw two indefinite perpendicular lines; then take the distance from *a* to *b* and describe the two half-circles; then, using the same radius, from point *c* find point *d* on the perpendicular, from which draw a horizontal line connecting at *e*; then, with the same raidus, find point *f*, from which draw a horizontal line connecting at *g*, thus forming the square, *d*, *e*, *f*, *g*. Then from *g* draw the line *gh*, equal in length to *gb*; then the line *ei*, then *ej*, *dk*, *dl*, and *fm*—all equal to *gb*; then connect *bh*, *hi*, *ij*, *jk*, *kl*, *lm*, and *ma*.

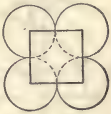
TO DIVIDE A CIRCLE INTO CONCENTRIC RINGS HAVING EQUAL AREAS.—Divide the radius, *ac*, Fig. 255, into as many parts as areas required, as 1, 2, 3, etc. With *ac* as a diameter draw the semicircle *a*, 4, 5, 6, *c*; draw lines from points 1, 2, 3 at right angles to *ac*, meeting the semicircle at 4, 5, 6; with *c* as centre and *c*4, *c*5, and *c*6 as radii draw the concentric circles.

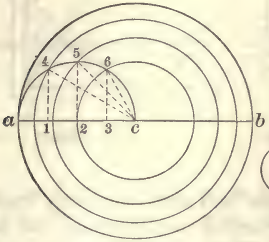
TO DRAW ANY NUMBER OF TANGENTIAL ARCS OF CIRCLES HAVING A GIVEN DIAMETER.—Draw a polygon of as many sides as arcs required (four and six). With each angle as centre and half of one side as radius draw the arcs, as shown in Figs. 256 and 257.

TO DRAW AN ELLIPSE.—Draw the rectangle *abcd*, Fig. 258. *ab* represents the long diameter and *ac* half the short diam-

eter; divide *ab* into two equal parts, as *ae* and *eb*; then divide *ae* and *ac* into the same number of equal parts, as 1, 2, 3, etc.;

FIG. 256.





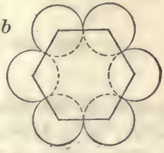


FIG. 255. FIG. 257.

then draw lines from *c* to 5, 6, 7, etc.; then draw lines from *e* to 1, 2, 3, etc.; then draw the curved line through the intersections, as shown.

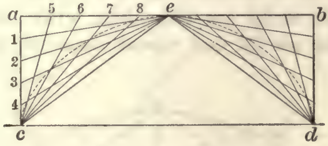


FIG. 258.

TO DRAW AN ELLIPSE WITH A STRING.—Draw the long diameter, Fig. 259, as *ab*; then half the short diameter, as *cd*; then, with *c* as centre and *ad* as radius, describe arcs bisecting *ab* at 1 and 2, at which points drive a nail to fasten the string; then fasten the string at 1 and stretch to *c*, at which point place a pencil inside the string and carry the string to 2 and make fast; then keep the string tight and run the pencil along on the inside of the string and the mark will be the ellipse; 3 and 4 show position of pencil and string on the curve.

TO DRAW AN ELLIPSE WITH THE SQUARE.—Take a strip of wood, as shown in Fig. 260, say $\frac{1}{2}'' \times 1''$, to use as a rule; then drive a nail through the stick about an inch from one end, as 1; then make the distance between 1 2 equal one-half the short

diameter of the ellipse and 2 3 equal to one-half the long diameter; drive another nail at 3 and at 2 make a hole for a pencil,

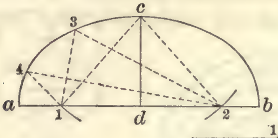


FIG. 259.

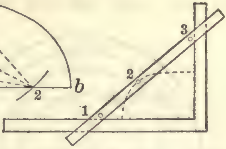


FIG. 260.

place the pencil in the hole and slide the stick from a perpendicular position to a horizontal one, keeping the nails against the inside of the square, and the pencil will describe an ellipse.

WHEN THE TWO AXES ARE GIVEN, TO DRAW A CURVE APPROXIMATING AN ELLIPSE.—With *cd* as the major axis and *ag* the minor axis, Fig. 261, draw lines connecting *ad* and *ac*; then, with *b* as centre and *ba* as radius, draw the semicircle, finding points *e* and *f*, from which points draw lines at right angles to *ad* and *ac*, intersecting at *g*; then, with *ga* as radius and *g* as centre strike arc 1 2; then, with *i* as centre and *i*2 as radius, strike arc 2*d* and repeat same for other side.

FIG. 261.

TO DRAW AN ELLIPSE WITH THE TRAMMEL.—Tack a frame to the floor or drawing-board, as shown by 1, 2, 3, Fig. 262, leaving a space between the strips of three-eighths of an inch; then, on the trammel, make *de* equal to the semi-minor axis and *df* equal to the semi-major axis; then put a $\frac{3}{8}$-inch pin in the trammel at *e* and *f* and place the same on the frame with

the pins in the slot; then draw the trammel around and *d* will describe the ellipse.

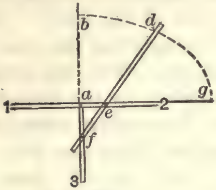


FIG. 262.

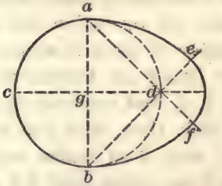


FIG. 263.

TO DRAW AN OVAL.—With *ab* as the short diameter and *ag* as radius, Fig. 263, draw a circle; then draw the line *cd* at right angles to *ab* through the centre *g*; then draw the lines *af* and *be* through *d*; then, with *b* as centre and *ba* as radius, draw the arc *ae*; then, with *a* as centre and same radius, draw the arc *bf*; then, with *b* as centre and *de* as radius, draw the arc *ef*.

UPON A GIVEN LINE, *ab*, TO DRAW AN OVAL.—Bisect *ab* at *c*, Fig. 264, and draw at right angles *cd*; with *b* as centre and *ba* as

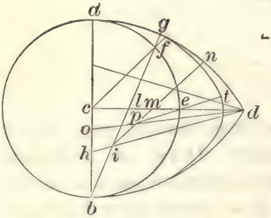


FIG. 264.

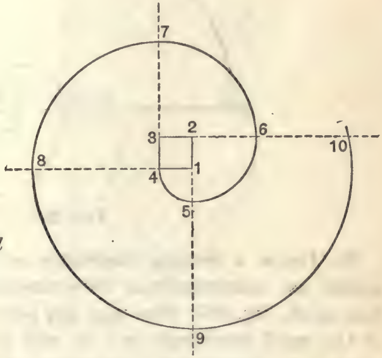


FIG. 265.

radius draw the arc *ad*. Bisect the quarter circle *ae* in *f* and through *f* draw *bg*, which gives *ag* as the first part of the curve. Now bisect *cd* in *h* and draw *hd*; then the intersection *i* is the centre and *ig* the radius for the second part of the curve. Bisect *el* in *m* and through *m* draw *in*, which gives *gn* as the second part of the curve. Bisect *ch* in *o* and draw *od*; the intersection

p is the centre and *pn* the radius for the third part of the curve. From *p* draw *pet* through *e* and *nt* is the third part of the curve; with *e* as centre and radius *et* draw the curve to the line *cd*. Repeat the operation for the other half of the curve. On the diameter *ab* draw a semicircle, thus completing the oval.

To Draw an Involute of a Square.—With the square as 1, 2, 3, 4, first continue the sides, as shown by the dotted lines, Fig. 265; then, with 1 as centre and 1 4 as radius, draw arc 4 5; then, with 2 as centre and 2 5 as radius, draw arc 5 6; then, with 3 as centre and 3 6 as radius, draw arc 6 7; then, with 4 as centre and 4 7 as radius, draw arc 7 8, etc.

To Draw a Spiral Composed of Semicircles whose Radii Shall be in Geometrical Progression.—Draw an indefinite line, as *ab*, Fig. 266. With 1 as centre and 1 2 as radius, draw first semicircle 2 3; then, with 2 as centre and 2 3 as radius, draw semicircle 3 4; then, with 3 as centre and 3 4 as radius, draw semicircle 4 5, etc.

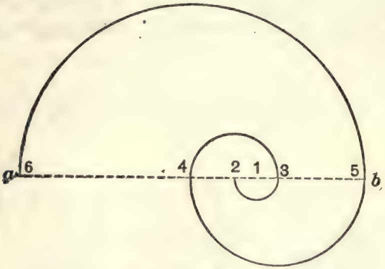


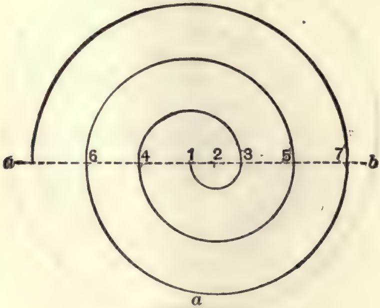
Fig. 266.

To Draw a Spiral Composed of Semicircles, the Radii being in Arithmetical Progression.—Draw an indefinite line, as *ab*, Fig. 267; then take any point as centre and the radius of the small semicircle, as 1 2; with 2 as centre draw the semicircle 1 3; then, with 1 as centre and 1 3 as radius, draw the semicircle 3 4; then, with 2 as centre and 4 2 as radius, draw the semicircle 4 5, etc.

To Draw a Spiral of One Turn.—First draw a circle, Fig. 268, as large as the spiral is to be; then divide it into any number of equal parts (in this case twelve), as lines *abc*, etc.; then divide any one of these lines into as many equal parts as the circle is divided; then with centre *c* and radius *c*11 draw

11e; then, with same centre and radius c10, draw arc 10f; then, with same centre and radius c9, draw arc 9g and continue until all the points are found; through these intersections draw the curves.

Fig. 267.



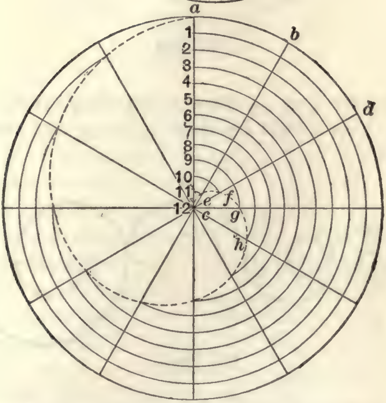


Fig. 268.

To Draw a Spiral of Any Number of Turns (in this Case Two).—Draw a circle the size of the spiral, Fig. 269, then divide it off into any number of equal spaces, say 12, as a, e, d, etc.; then divide any radius, as ac, into as many equal parts as there are turns to the spiral; then divide these spaces into as many equal parts as the circle, as 1, 2, 3, 4, etc.; then, with c as centre and c2 as radius, draw arc intersecting ec; then, with c as centre and c3 as radius, draw arc intersecting dc, etc.; continue up to

12; then commence with c as centre and $c+2$ as radius and draw arc to ec; then through these points draw the curve.

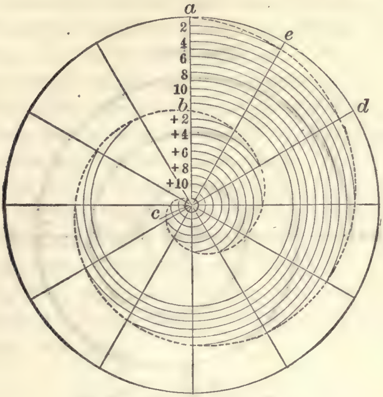


FIG. 269.

Fig. 270 shows how to draw a tapering scroll composed of semicircles; these scrolls are used in laying out vines and other ornamentation.

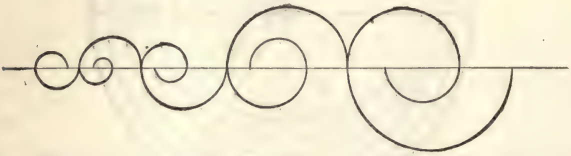


FIG. 270.

TO DRAW A SCROLL FOR A STAIR RAILING.—Draw the eye of the scroll, as the circle *acbd*, Fig. 271; draw the diameters *ab* and *cd*; connect *c* and *b*; bisect *co* at *e* and draw *el* parallel to *ab*; draw a line from 6 parallel to *cd*, as 6*k*; bisect *eo* at 3 and draw 3 2; make *o*4 equal to *o*3 and draw *j*5 parallel to *ab*; bisect *o*7 and draw 1 2; with 1 as centre and 1*f* as radius draw arc *fg*; with 2 as centre and 2*g* as radius draw arc *gh*; with 3 as centre draw arc *hi*, etc. To draw the inner curve take 7 as centre and 7*f* as radius and draw arc *fm*; with 6 as centre and 6*m* as radius draw arc *mn*.

To Draw a Spiral when its Greatest Diameter is Given (in this Case One of Three Turns).—Divide the diameter

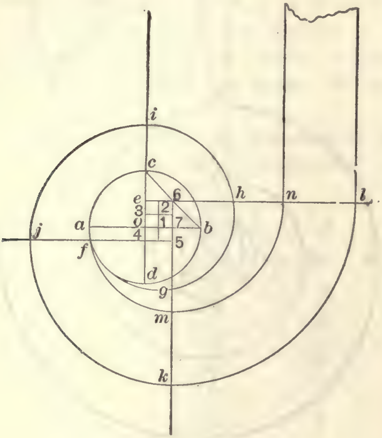


Fig. 271.

op, Fig. 272, into eight equal parts, as 1, 2, 3, etc.; with 4 5 as diameter draw the circle *acbd* for the eye of the spiral. Draw the two diameters *ab* and *cd* and divide them into twice as many equal parts as there are turns to the spiral, as 1, 2, 3, 4, 5, 6, etc., in the enlarged eye. Now, with 1 as centre and 1*b* as radius draw the arc *bf* to strike a horizontal line from 2 through 1; with 2 as centre and 2*f* as radius draw arc *fg* to strike a perpendicular line from 3 through 2; with 3 as centre and 3*g* as radius draw arc *gh* to strike a line from 4 through 3, and so continue until the spiral is completed.

In a spiral of one turn the diameter of the eye is about three-tenths of the length of the greatest diameter; in one of two turns, about one-sixth; in one of three turns, about one-eighth; in one of four turns, about one-tenth.

To Draw an Ionic Volute.—Let *ab* be the vertical measure of the volute, Fig. 273; divide *ab* into seven equal parts and from point 4 draw a line at right angles to *ab*; at any point on this line draw a circle whose diameter is equal to one of the divisions on *ab*. Draw the square *abcd*; bisect each of its sides and draw the square *e*12, 11*f*; draw the diagonals *e*11, *f*12;

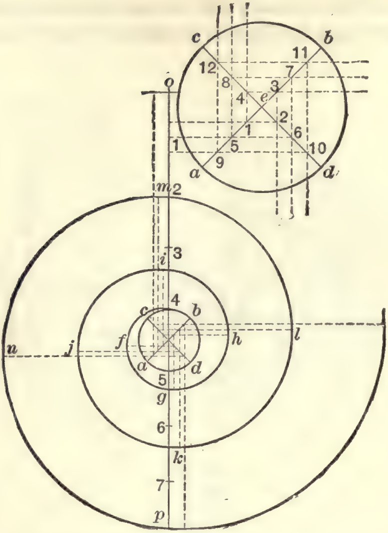


FIG. 272.

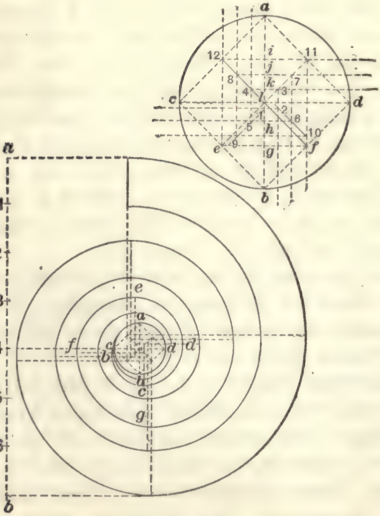


FIG. 273.

divide the diagonal 12l into three equal parts and draw 8 7 and 4 3 and continue the lines as shown, making hg equal to one-half ij; with 1 as centre and 1a as radius draw arc ab to meet a line through 1 and 2; with 2 as centre and 2b as radius draw arc bc to meet a line through 2 3; with 3 as centre and 3c as radius draw arc cd to meet a line through 4 3, etc. The centres to draw the inner curve are shown by the dots on the diagonals, which is the centre of the space between the angles of the squares.

To Draw a Parabola when the Abscissa ab and the Ordinate ac are Given.—Draw the rectangle $abcd$, Fig. 274, and

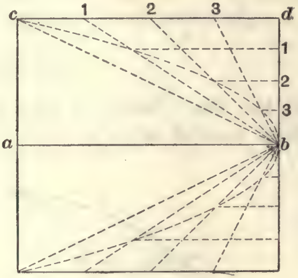


Fig. 274.

divide cd and db into the same number of equal parts; draw lines from b to meet points 1, 2, 3, etc., on cd; then draw lines from points on db parallel to ab; draw line 1 until it intersects 1b; draw line 2 until it intersects 2b, etc.; these intersections are points on the line of the curve.

To Draw an Hyperbola when the Diameter, ab, the Abscissa, bc, and the Double Ordinate, de, are Given.—Complete the rectangle $bcdf$, Fig. 275, and divide fd and dc into the same number of equal spaces, as 1, 2, 3, etc.; from b draw b1, b2, etc., and from a draw the intersecting lines a1, a2, etc.; through the intersections of these lines draw the curve bd. Repeat for the other half of the curve.

To Draw a Cycloid.—Draw the rolling circle, as b, 1, 2, 3, etc., Fig. 276, and divide the semicircle into any number of equal parts, as 1, 2, 3, etc.; make the spaces on ab equal to those on the semicircle; draw a line from d parallel to ab; draw lines from the points on ab perpendicular to meet the line ed at ooo,

which are the centres of the rolling circle in its several positions; with these points as centres and the radius of the rolling circle

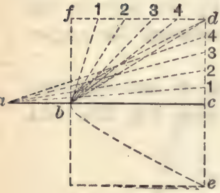


Fig. 275.

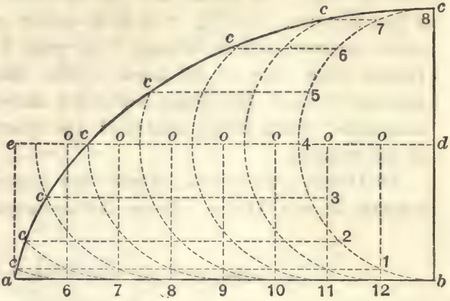


Fig. 276.

draw the arcs 12*c*, 11*c*, 10*c*. From 1 2, etc., the points on the semicircle, draw lines parallel to *ab* to meet the arcs 12*c*, 11*c*,

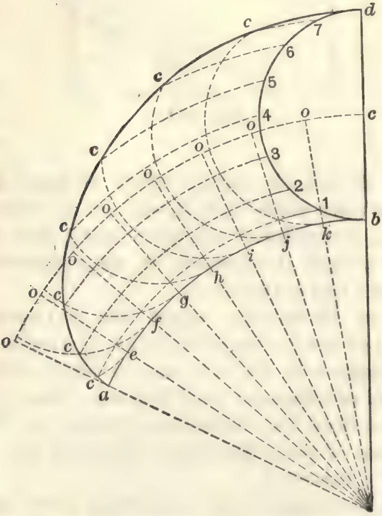


Fig. 277.

etc., at *cc*, etc.; draw the curve through points *c*, *c*, *c*, etc. For the other half of the curve reverse and proceed as above.

To Draw an Epicycloid; also to Draw a Hypocycloid.—Draw the curve of the directing circle, as *ab*, Fig. 277, and the curve of the rolling circle, as *b*, 1, 2, etc.; divide the semicircle *bd* into any number of equal parts, as 1, 2, 3, etc.; make the spaces on *ab* equal to those on the semicircle *bd*, spacing from

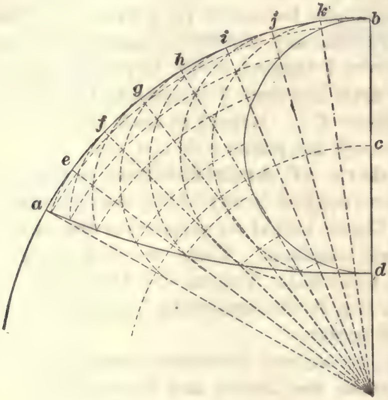


Fig. 278.

b; with the centre of the directing circle as a centre, draw an arc from *c*, giving the line of centres of the rolling circle. Draw lines from the centre of the directing circle radiating through

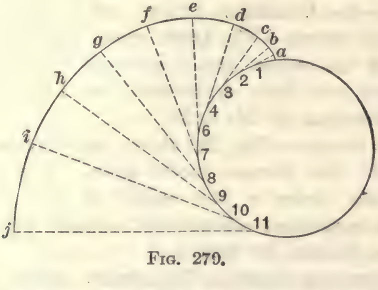


Fig. 279.

the points *k*, *j*, *i*, etc., thus finding the centres of the rolling circle in its several different positions, as *o*, *o*, *o*, etc.; with these points as centres and radius of the rolling circle draw the arcs *k*, *c*, *j*, *c*, etc.; with the centre of the directing circle as centre

draw arcs from 1, 2, 3, etc., to meet the arcs from *e*, *f*, *g*, etc.; the intersections of these arcs are points on the curve, as shown; draw the curve through the points *c*, *c*, *c*, etc. To draw the hypocycloid, see Fig. 278. When the diameter of the rolling circle is equal to the radius of the directing circle the hypocycloid becomes a straight line.

To Describe the Involute of a Circle.—Divide the given circle, Fig. 279, into any number of equal spaces, as 1, 2, 3, etc.; draw a line from 2 tangent to the circle and equal in length to the arc 1 2; draw line from 3 tangent to the circle and equal in length to the arc 3 1. Repeat at each of the points and draw the curve through the points *a*, *b*, *c*, *d*, etc.

The Orders of Architecture. — Order of Architecture is the term applied to any of the systems used by the architects of the Classic period to proportion the various parts and details of their buildings. There are five of these orders—the Doric, Ionic, Corinthian, Tuscan, and Composite.

Each order has its distinguishing features, as will be seen by the following figures.

The Doric, Ionic, and Corinthian orders were originated by the Greeks, while the Tuscan and Composite orders are modifications or improvements made by the Romans.

Each order consists principally of three divisions—the Stylobate, which forms the base or foundation; the Column, which is the shaft which supports the superstructure and which is usually composed of a base, shaft, and capital; and the Entablature, which is the superstructure proper. It consists of three principal divisions—the Architrave, Frieze, and Cornice.

The Doric Order.—The Doric order, Fig. 280, is the most ancient of all the orders, and is also the most simple; it has few members and little ornamentation. Fig. 281 shows the Roman modification of this order.

The Ionic Order.—Fig. 282 shows the Grecian Ionic order, and Fig. 283 the Roman modification. The distinguishing feature of this order is the capital of the column, which consists of a contracted echinus and a small torus, over which the spirals or volutes are turned.

The Corinthian Order.—This order, shown by Fig. 284, is the most elaborate of the three Grecian orders; the column is more slender than the preceding orders and the capital has more enrichment. The ornament on the Corinthian capital consists of a number of caules, or husks, out of which the cauli-

culi, or twisted stems, spring, forming small spirals or volutes at the sides and angles of the abacus. Fig. 285 shows the Roman modification of the order.

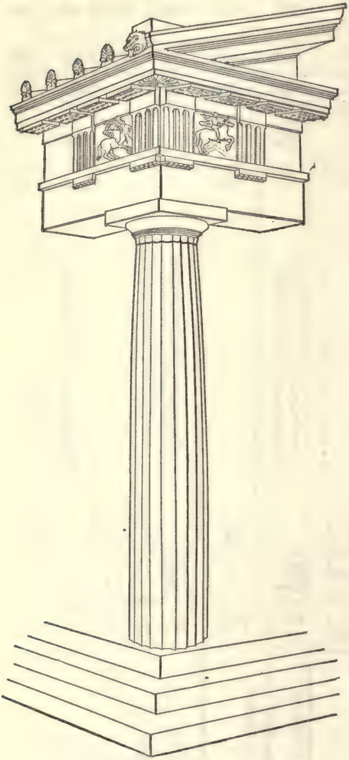


Fig. 280.

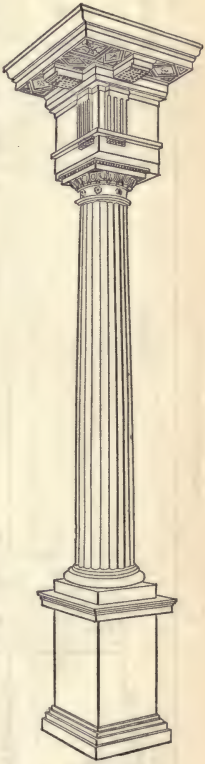


Fig. 281.

The Tuscan Order.—This is the most simple of the Roman orders, as is shown by Fig. 286. In the Roman orders the pedestal is always one-third and the entablature one-fourth the height of the column.

The Composite Order.—This order, shown by Fig. 287, was invented by the Romans to secure something more elab-

Name of Order.				Grecian Doric.		Grecian Ionic.		Grecian Corinthian.	
				H.	P.	H.	P.	H.	P
Orders of Architecture.	Entablature.	Cornice. .	Cymatium Corona Bed-mould	23	$55\frac{1}{2}$	$37\frac{3}{5}$	$63\frac{7}{20}$	$48\frac{1}{2}$	81
		Frieze.	....	$42\frac{3}{5}$	$28\frac{3}{10}$	$47\frac{3}{4}$	$27\frac{1}{10}$	44	$31\frac{1}{4}$
		Architrave.	Tænia......	$42\frac{2}{3}$	$28\frac{3}{10}$	$50\frac{3}{4}$	28	$52\frac{1}{2}$	30
	Column.	Capital...	Abacus.	.....	32	.....	34	.....	47
			Echinus. ...	$27\frac{1}{2}$	.....	$43\frac{7}{20}$	.....	$85\frac{1}{2}$	.....
			Necking. ...	.....	.....	.....	.....	.....	.....
		Shaft.	Astragal. ...	.....	$23\frac{1}{5}$	.....	25	.....	25
				5 diameters, $2\frac{1}{4}$ minutes.		7 diameters, $52\frac{49}{60}$ minutes.		8 diameters, $12\frac{1}{8}$ minutes.	
			Cincture. ...	.....	30	.....	30	.....	30
		Base of Column.	Base mould.	No	.....	$23\frac{5}{6}$			
			Plinth......	base	.....	$22\frac{1}{8}$	$47\frac{9}{10}$	$22\frac{1}{3}$	$46\frac{2}{3}$
	Stylobate, or Pedestal.	Cap.	Corona. Bed-mould.	....		....			
		Die.		Stylobate of 3 steps, $50\frac{1}{15}$ minutes.		No pedestal			
		Base....	Base mould. Plinth......						

Roman Doric.		Roman Ionic.		Roman Corinthian.		Composite.		Tuscan.	
H.	P.	H.	P.	H.	P.	H.	P.	H.	P.
45	86¾	52½	76⅔	60	88⅓	60	85	40	68¾
45	25	45	25	45	25	45	25	35	23¾
30	25	37½	25	45	25	45	25	30	23¾
....	39½	......	33⅓	......	45	......	45	......	36¼
30	....	25	......	70	......	70	......	30	
....	25	......	25	......	25	......	25	......	23¾
7 diameters.		8 diameters, 3 minutes.		8 diameters, 17½ minutes.		8 diameters, 17½ minutes.		6 diameters.	
....	30	......	30	......	30	......	30	......	30
30	42½	32	42	32½	41⅔	32½	41⅔	30	41¼
15	57½	16⅔	58⅔	25	55⅝	25	55	15	51¼
....	42½	......	42	......	41⅔	......	41⅔	......	41¼
2 diameters.		2 diameters, 26⅔ minutes.		2 diameters, 30 minutes.		2 diameters, 33⅓ minutes.		2 diameters, 50 minutes.	
25	53¾	16⅔	55½	25	54⅙	21⅔	55	15	51¼

orate than the Corinthian order; as will be seen, it is a combination of the Ionic and Corinthian.

PROPORTIONS OF THE VARIOUS ORDERS OF ARCHITECTURE.—All the different members of the various architectural orders

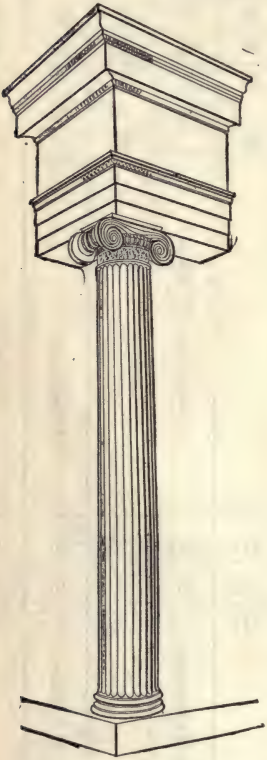


FIG. 282.

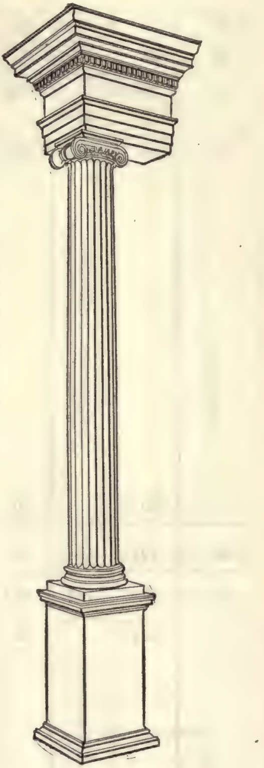


FIG. 283.

are proportioned from the large diameter of the column. For convenience we divide this diameter into sixty parts, called minutes or parts, and the different members are proportioned by this scale.

The chart on pp. 550, 551 shows the sizes of the members of the different orders, the figures denoting sixtieth parts of the diameter, or minutes. Those in the columns marked

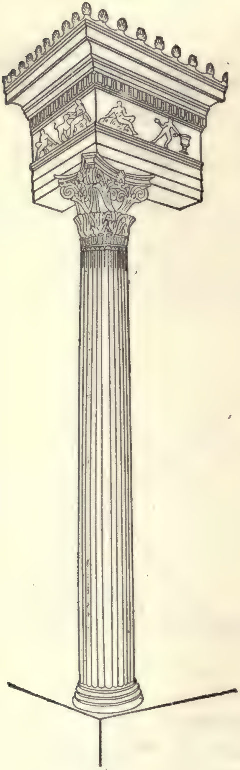


Fig. 284.

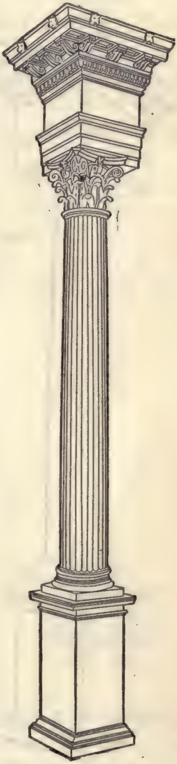


Fig. 285.

H are the heights, and those in the columns marked P give the projection of the member from the centre line or axis of the column.

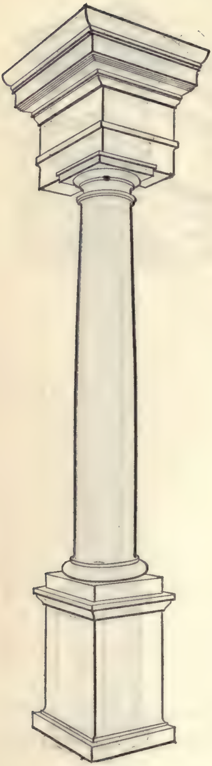


FIG 286.

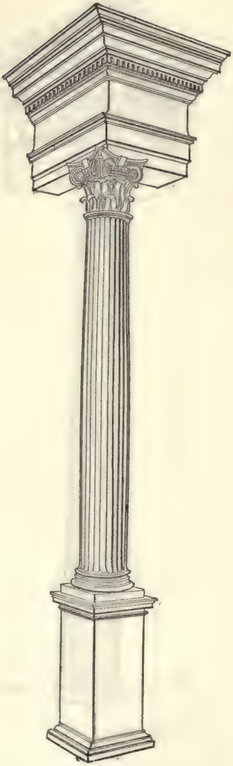


FIG 287.

Laying Out Work, etc.—To Approximate the Number of Squares in a Roof.—If $\frac{1}{3}$ pitch, find the floor surface and multiply by $1\frac{1}{3}$; if $\frac{1}{2}$ pitch, multiply by $1\frac{1}{2}$; if $\frac{1}{4}$ pitch, multiply by $1\frac{1}{4}$, etc.

Example.—Find the number of squares in a roof 30×40 feet, $\frac{1}{2}$ pitch: $30 \times 40 = 1200$; $1200 \times 1\frac{1}{2} = 1800$, or 18 squares.

The Length of Rafters for the Most Common Pitches may be found as follows:

One-quarter pitch, multiply the span by 0.559; $\frac{1}{3}$ pitch, multiply the span by 0.6; $\frac{3}{8}$ pitch, multiply the span by 0.625; $\frac{1}{2}$ pitch, multiply the span by 0.71; $\frac{5}{8}$ pitch, multiply the span by 0.8; Gothic or full pitch, multiply by 1.12.

Backing of Hip-rafters.—Draw 1 2 and 2 3, Fig. 288, to represent the plates of the building, then the seat of the hip, as 2 4; then the hip, as 2 5. Take any point of the hip, as *c*, and draw a line at right angles to 2 5 until it strikes the seat, 2 4; then continue the line at right angles to the seat, or 2 4,

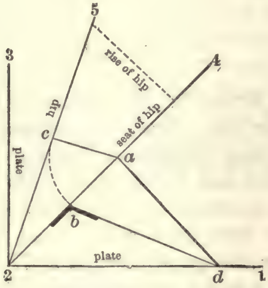


Fig. 288.

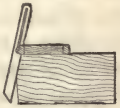


Fig. 289.

until it strikes the plate, as point *d*; then, with *a* as centre and *ac* as radius, strike an arc bisecting 2 4 at *b*; then draw line from *b* to point *d* on the plate; then the bevel at *b* is the bevel for backing the hip. Fig. 289 shows application.

To Find the Bevel for Backing the Hip-rafters for an Octagon Roof.—Draw the plate as *ade*, Fig. 290; then draw the common rafter, as *ab*; then the seat and full size of hip, as *df*; then draw line from 5 to 6; then, with *d* as centre and *d*1 as radius, describe arc 1 2; then draw line from 2 parallel to *ad* to point 3, and continue parallel to *ab*. Then lay off

the thickness of the rafter on 3 4, and draw the bevel lines as shown. This rule applies to any roof.

To Find the Bevel for Backing Hip-rafters.—Take the length of the hip on the blade of the square and the rise of the roof on the tongue and the tongue will give the desired bevel.

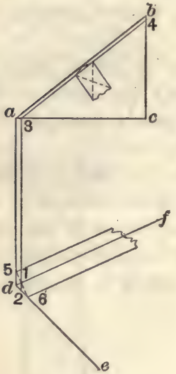


Fig. 290.

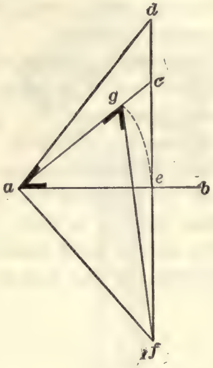


Fig. 291.

To Get the Bevels to Mitre Purlins when the Purlin sets Square with the Rafters.—Draw *ace*, representing the slope of the roof, Fig. 291; then continue *ce*, making it equal in length to *ac*, as *de*; connect *a* and *d*, thus finding the bevel for the top or face of purlins, as shown at *a*. Now drop the perpendicular from *e* indefinitely; then draw a line from *a* at right angles to *ac* until it strikes the perpendicular at *f*. Make *ag* on *ac* equal to *ae*; connect *g* and *f*, and the bevel at *g* will be the bevel for the side of the purlin.

To Find the Lengths and Bevels of Hip- and Cripple-rafters.—Draw the plates as *ab* and *bc*, Fig. 292, then the seat of the hip, as *bd*, then the seats of the cripples, as 1 1, 2 2, 3 3, etc.; then draw the rise of the common rafter, as *de*, then *e* to 1 is the length of the common rafters; then draw the rise of the hip, as *df*, then *fb* is the length of the hip; then continue the seat of the common rafter until it equals the length of the rafter as 1*g*; then draw *gb*, which is equal to the length of the hip, then continue the seats of the cripples until they strike the hip, *gb*, which gives the lengths of the cripples, also the top bevel, which is shown at *h*; then draw line from *g* parallel to

de, which gives the top bevel of the hip as shown at *g*, but the bevel must not be used until after the hip has been backed. The length

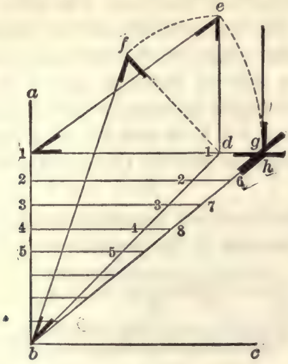


FIG. 292.

of the cripples are shown by the lines 2 6, 3 7, 4 8, etc. The bevel at *b* is the bevel of the foot of the hip; the one at the top is shown at *f*. The bevel of the foot of the common and cripple rafters is shown at *e*. The top bevel of cripple is shown at *h*.

TO FIND THE BEVELS TO CUT SHEATHING FOR A ROOF.—Draw level line, as *ab*, Fig. 293, then draw *cb*, showing the pitch of the roof; then from any point on this line let fall a perpendicular, as *dg*; then let fall a perpendicular from *b*, as *bf*. Now, with *d* as centre and *db* as radius, strike an arc intersecting *ab* at *e*;

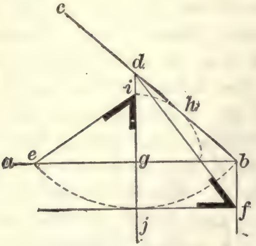


FIG. 293.

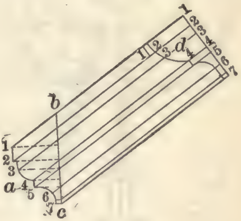


FIG. 294.

now, from the intersection of the perpendicular line, *dg*, produced at *j*, draw line parallel to *ab*, intersecting perpendicular, *bf*; now from this point draw a line to *d*, thus giving the bevel for the face of the board. Then, with *g* as centre and *gh* as radius, strike an arc at *i*; then draw a line from *i* to *e*, thus giving the bevel for the edge of the boards.

TO LAY OUT A RAKE MOULDING TO JOIN THE MOULDING ON THE SQUARE SET ON A PLUMB FACIA.—Mark out the square moulding, as *a*, with *bc* as the facia, Fig. 294; then draw lines at right angles to the facia, joining all the breaks in the moulding, as 1, 2, 3, 4, etc.; then draw lines from these points on the moulding with the rake of the roof, as 1 1, 2 2, 3 3, etc., and draw a line at right angles to these, as 1 7 at *d*; make line 1 1 at *d* the same length as 1 1 at *a* and 2 2 at *d* same as at *a*, etc.; then join these points as shown, thus giving the profile of the rake moulding.

TO REDUCE A SQUARE STICK TO AN OCTAGON.—Place the blade of the square on the stick in the position shown in Fig. 295, and

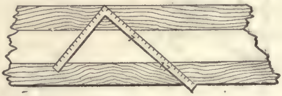


FIG. 295.

7 and 17 on the blade will give the chamfer lines, as shown.

TO LAY OUT PERPENDICULAR SHEATHING FOR A DOME ROOF.—Draw the spring of the roof, as *adb*, Fig. 296, and divide it in half by *cd*; then divide *db* into equal parts (as many as desired), and from these points let fall perpendiculars to the base line *cb*; then with *c* as centre, continue these lines as semicircles, as shown by the dotted lines; then continue the line *dc* indefinitely; now on the outside of the circle lay off the width desired for the boards at the base, as 5 5, and draw a line from this point to *c*, as *c*5; this shows the ground plan and width of the board at the several different points. Now on the indefinite line make 5 11 equal to *db* on the circle; this is the length of the board. Then divide this line into as many equal parts as the circle of the roof and make 6 6 equal to 1 1, 7 7 equal to 2 2,

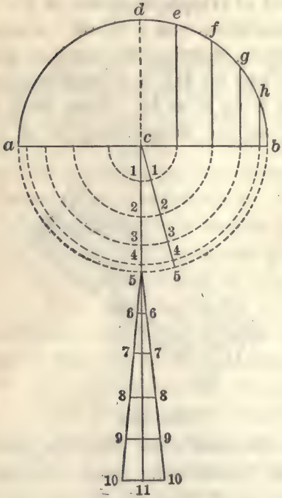


FIG. 296.

8 8 equal to 3 3, etc.; now connect 5 6, 6 7, etc., which gives the pattern of the sheathing boards.

The same rule applies to any shape roof having a circular base.

TO LAY OUT HORIZONTAL SHEATHING FOR A DOME ROOF.—Draw the roof as shown by *abc*, Fig. 297, and divide it in half by a perpendicular line, which continue up indefinitely; then divide *ab* into as many spaces as you desire boards, as 1, 2, 3, etc. Then draw a line from *a*, striking point 1, and continue until it bisects the perpendicular, which is the centre, and this point and *a* and this point and 1 is the radius for the first board; then draw a line from 1 through 2 and continue to the perpendicular, thus giving the centre and radius for second board; then draw the line 2 6 and repeat the operation, etc.

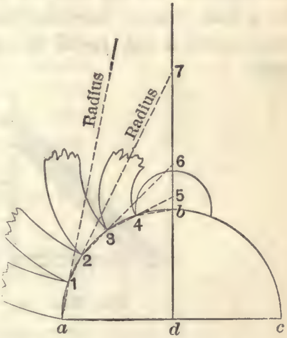


FIG. 297.

This rule applies to any shape roof of a circular base.

TO GET THE LENGTH AND CUT OF CRIPPLE-RAFTERS IN A CURVE ROOF.—Draw the plates, as *ab* and *bc*, Fig. 298, and the seat of the hip, as *ac*. Now draw the rise and profile of the common rafter, as *ce* and *eb*; lay off the seats of the cripples, as

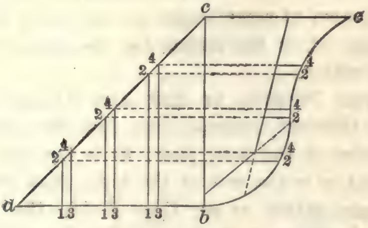


FIG. 298.

1 2, 3 4, etc., making 1 3 the thickness of the cripple rafter. Now continue these lines from where they strike the seat of the hip parallel to *ab* until they strike the profile of the common rafter; then *b*4 will be the length of the cripple, 4 will be the

long length and 2 the short length, or 4 will be the line of the cut on one side and 2 the line of the cut on the other side.

To Get the Cut of Braces where Their Diagonal is Plumb when in Position.—(As shown in Fig. 299.) Take the run of the brace, multiplied by 0.70711, on the blade of the square and the rise on the tongue, and the angle formed by a line drawn between these two points and the blade of the square is the bevel to cut the brace, applied on all four sides.

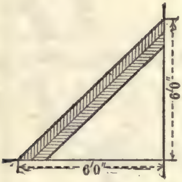


Fig. 299.

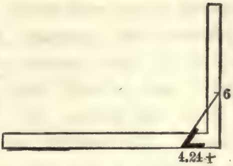


Fig. 300.

Example.—Find the cut of a brace 6 feet run and 6 feet rise. The run, 6 feet, by 0.70711 = 4.24266. Now draw a line from 4.24+ on the blade to 6 on the tongue, and the bevel on the blade is the bevel to cut the brace, as shown in Fig. 300. For the top multiply the rise by 0.70711 and proceed as above.

To Lay Out the Plancher for a Conical Roof.—The following diagram, Fig. 301, will show how to lay out the plancher for a conical roof: *a* and *b* is the radius for the plancher, and *cd*, which is drawn at right angles to the rafter until it strikes the centre line, *ad*, is the radius for the facia, if it is put on square to the rafter.

To Find the Profile of Hip- and Valley-rafters for Concave or Convex Roofs.—In Fig. 302, *bcde* represents a quarter section of the floor plan; *bc* is the seat of the common rafter and *ce* is the seat of the hip. Now draw the profile of the common rafter, as *ac*; then divide the base, *bc*, into any number of spaces, 1, 2, 3, etc., and through these spaces draw lines at right angles to *bc*, continuing then to the profile of the common rafter, *ac*, and the seat of the hip, *ec*; then from these intersections on the seat of the hip continue the lines at right angles to the seat of the hip, making the line 1 1 on the hip equal to 1 1 on the common

rafter, and 2 2 on the hip equal to 2 2 on the common rafter, 3 3 equal to 3 3, etc The points thus found by these lines are points on the profile of the hip; connect *c*1, 1 2, etc., as shown, thus giving profile of hip.

To Lay Out the Joints in an Elliptic Arch.—Draw the arch *abc*, Fig. 303, and divide the curve into equal spaces, as 1, 2, 3, etc., making as many spaces as joints required in the arch; draw lines from the foci *dd* to the points on the curve and bisect the angle thus formed, as shown. The lines bisecting this angle are the lines of the joints. Repeat the operation for each joint.

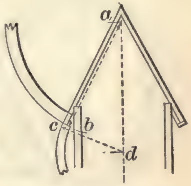


Fig. 301.

To Lay Off an Octagon Bay when the Length of One Side is Given.—First draw a line to represent the side of the house, as *ab*, Fig. 304; then with the trammel set the length of the side, place the foot at *a* and find point *d*; make the distance from *d* to *c* five-twelfths of *ad*; then, with the foot of the compasses at *c*, find point *b*; with the foot at *b*, strike the arc *cf*; with the foot at *d*, find point 1; with the foot at *a*, strike the arc *de*; with the foot at *c*, find point 2; then connect *ae*, *ef*, and *fb*.

To Lay Out a Hexagon Bay Window when the Length of One Side is Given.—Draw the line *ac* as side of the house, Fig. 305; then, with *a* as centre and the given side as radius, strike arc *db*; then, with *b* as

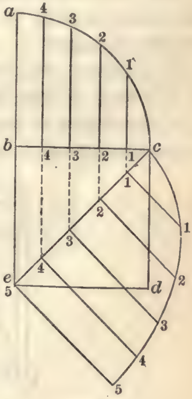


Fig. 302.

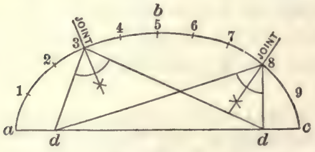


Fig. 303.

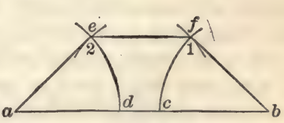


Fig. 304.

centre, find point *c*; then, with *c* as centre, strike arc *eb*; now with *b* as centre, strike semicircle *adec*; now connect *ad*, *de*, and *ec*.

To find the side of an octagon bay when the length on the house is given: Divide the distance on the house by $2\frac{5}{12}$, and the answer will be the length of the side.

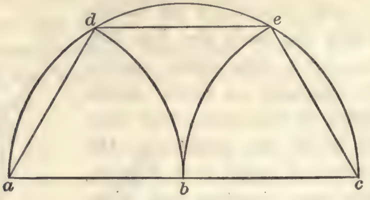


FIG. 305.

To find the distance on the house when the side is given: Multiply the side by $2\frac{5}{12}$, and the answer will be the diameter of the octagon.

TO STRIKE AN OGEE FOR A BRACKET.—Lay off the width and length of the bracket, as *ac* and *ab*, Fig. 306; then draw the line shown at the back of bracket an inch, or more if desired, from the edge of board; then draw the diagonal *cd*; then divide

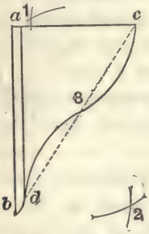


FIG. 306.

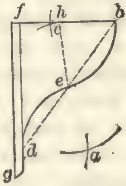


FIG. 307.

cd into two equal parts at 3; then, with 3 as centre and 3*c* as radius, strike arc at 1; then, with *c* as centre and same radius, strike arc intersecting at 1; then, with 1 as centre, strike arc *c*3; then, with 3*d* as centre, strike arcs intersecting at 2; then, with 2 as centre, strike arc 3*d*.

ANOTHER WAY TO LAY OFF A BRACKET.—With *fg* as edge of board and *fb* as end or top of bracket, Fig. 307, draw the dotted line, as shown; then draw the diagonal *ab* and divide it into two equal parts at *e*; then, with *eb* as centres and *eh* as radius, strike arcs intersecting at *c*; then, with same radius and *c* as centre, strike arc *be*; then, with same radius and *ae* as

centres, strike arcs intersecting at *d*; then, with *d* as centre, strike arc *ea*.

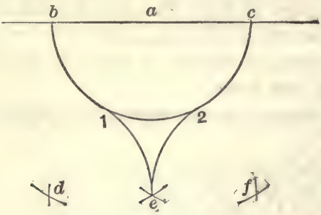


FIG. 308.

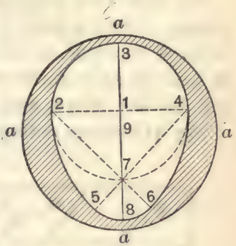


FIG. 309.

TO LAY OUT THE VENTILATING HOLE OF A PRIVY DOOR.—*bac* represents the top edge of the door, Fig. 308; with *a* as centre and the desired radius, draw the semicircle *b* 1 2 *c*; now, with *bc* as radius and *b* and *c* as centres, draw arcs intersecting at *e*; then, with same radius and *a* as centre, draw arcs at *d* and *f*; now, with *ac* as radius and *e* as centre, draw arcs intersecting these at *d* and *f*, and with same radius and these intersections as centres, draw the arcs 1*e* and 2*e*.

TO LAY OUT A PRIVY SEAT.—Draw two lines at right angles to each other, as 2 4 and 3 8, Fig. 309; make 2 4 about

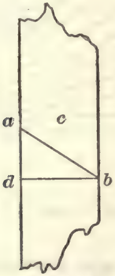


FIG. 310.

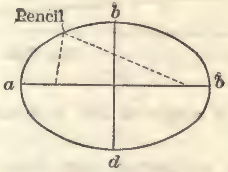


FIG. 311.

8 inches long; with 1 as centre and 1 4 as radius, draw a circle; now draw lines from 2 and 4 through 7; then, with 2 4 as radius and 2 4 as centre, draw the arcs 4 6 and 2 5; now, with 7 as centre and 7 6 as radius, draw the arc 5 6, completing the oval; now find the centre of the line 3 8, as 9, and with this

point as centre and 2 7 as radius, draw the circle *aaaa*; saw out to the oval line and round off to the circle.

To Lay Out a Hole in a Roof for a Stovepipe or Flag-staff.—Draw a section of the pipe or staff, as *c*, and lay off the slope of the roof, as *ab*, and the run as *db*, Fig. 310; now, with *ab* and *db* as axis, draw an ellipse, as shown at Fig. 311, which will be the shape and size of the hole.

Fig. 312 shows a diagram to obtain cuts or degrees on a square;

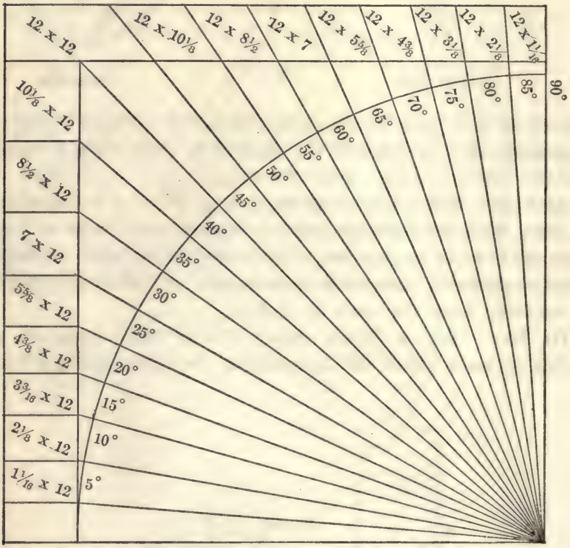


Fig. 312.

for instance, if angle of 30° is desired 7 and 12 on the square will give it.

To Mitre a Circle and Straight Moulding.—Draw a full-size plan of the two mouldings, as shown in Fig. 313; draw *abc*, as shown, in the centre of the space between the two outside lines; connect *d* and *b* and *b* and *c*; bisect *db* and *bc* and draw lines at right angles to them to meet at *f*; then *fd* is the radius of the mitre joint.

To Find Mitres on the Steel Square.—12×12 equals square mitre; 7×4 equals triangle mitre; 13¾×10 equals

pentagon mitre; 4×7 equals hexagon mitre; $12\frac{1}{2}\times6$ equals heptagon mitre; 7×17 equals octagon mitre; $22\frac{1}{2}\times9$ equals nonagon mitre; $9\frac{1}{2}\times3$ equals decagon mitre.

All plumb lines radiate from the centre of the earth, showing

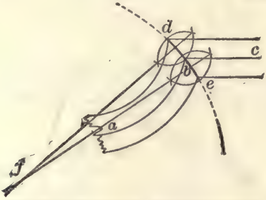


Fig. 313.

that if it were possible to make walls perfectly plumb they would not be parallel.

All level lines are at right angles to an imaginary line from the centre of the level to the centre of the earth. If a line

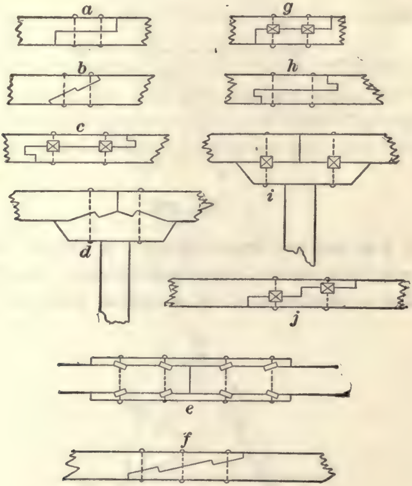


Fig. 314.

is drawn parallel to the earth's surface it has a curve of eight inches to the mile.

Fig. 314 shows some of the various methods of splicing or joining timber.

To Lay Out Arches.—LANCET GOTHIC ARCH.—A lancet Gothic arch is one whose radius is greater than its width, as shown in Fig. 315.

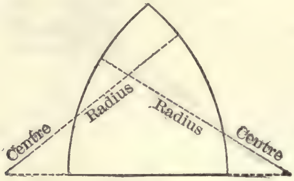


FIG. 315.

TO DRAW THE GOTHIC ELLIPTICAL ARCH.—Divide the span *ab* into three equal parts at *c* and *d*, Fig. 316; with *bc* as radius

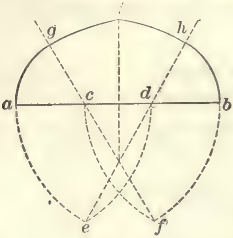


FIG. 316.

and *a*, *c*, *d*, *b* as centres, draw the arcs, as shown, finding points *e* and *f*; now, from *e* and *f* draw lines through *c* and *d*, as shown; with *c* and *d* as centres and *ac* as radius draw arcs *ag* and *hb*,

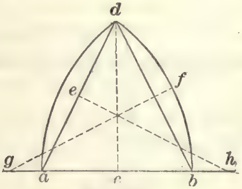


FIG. 317.

and with *e* and *f* as centres and *eh* as radius draw arcs *gi* and *ih*, completing the curve of the arch.

TO DRAW THE LANCET GOTHIC ARCH WHEN THE SPAN AND RISE ARE GIVEN.—On the base line, Fig. 317, mark the span *ab* and from the centre draw the rise *cd*; now connect *ad* and *db*, and from the centre of these lines draw a line at right angles to strike the base line, as *gf* and *eh*; now *g* is the centre and *gb* the radius to draw the arc *db*, and *h* the centre and same radius to draw the arc *ad*.

GOTHIC ARCH.—The most common Gothic arch is one whose radius is equal to its width, as shown in Fig. 318.

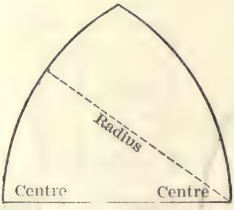


FIG. 318.

All Gothic arches are easily struck from the centre, usually shown on the drawings.

TO DRAW A FLAT-POINTED ARCH TO A GIVEN WIDTH AND RISE.—Draw the width, as AB, Fig. 319, and the height, as OC, while CD is a line tangent to the upper circle; now draw $C3$ at right angles to DC, and from A draw the perpendicular AD; now find point I,

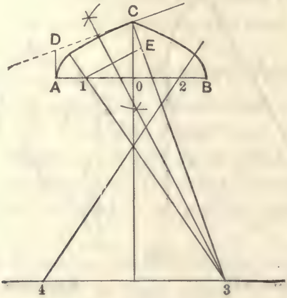


FIG. 319.

making AI equal to AD; now find point E, making CE equal to AD, and connect I and E; now bisect the line EI, as shown,

and draw a line to meet $C3$; now from 3 draw a line through point I as $3D$, and I and 3 will be the centres to strike the arch; then transfer the points across to 2 and 4 for the centres for the other half.

DROP ARCH.—A drop arch is one whose radius is less than its width, as shown in Fig. 320.

Another form of drop arch is shown in Fig. 321.

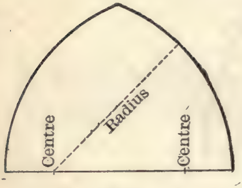


FIG. 320.

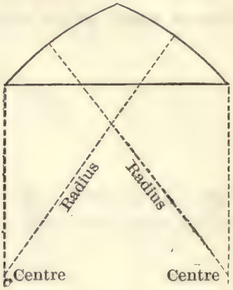


FIG. 321.

THREE-CENTRE ARCH.—With ab as width of arch and e as centre, Fig. 322, take ea as radius and strike semicircle ab; then, with a as centre and ab as radius, strike arc bc; then,

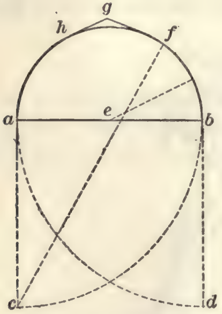


FIG. 322.

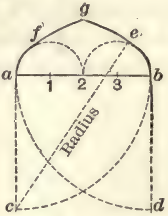


FIG. 323.

with b as centre and same radius, strike arc ad; then, with c as centre and cf as radius, strike arc gf; then, with d as centre and same radius, strike arc gh, thus completing the arch.

FOUR-CENTRE ARCH.—To strike a four-centre arch divide the width into four equal spaces, as 1, 2, 3, Fig. 323; then, with 1 as centre and 1*a* as radius, strike semicircle *a*2; then, with 3 as centre and same radius, strike semicircle 2*b*; then, with *ab* as radius and *a* as centre, strike arc *bc*; then, with same radius and *b* as centre, strike arc *ad*; then, with *c* as centre and *ce* as radius, strike arc *ge*; then, with same radius and *d* as centre, strike arc *fg*, completing the arch.

TO DRAW THE TUDOR OR GOTHIC ARCH.—Let *ab* be the span and *cd* the rise, Fig. 324; with *ab* as radius and *c* as centre

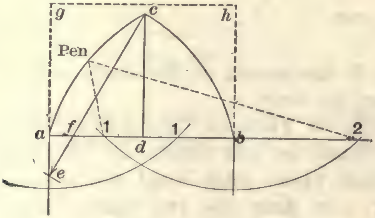


FIG. 324.

draw an arc through the perpendicular at *e*, connect *c* and *e*, make *ag* and *bh* equal to *cf*; now, with *ab* as radius and *g* and *h* as centres, find points 1 1 and 2 2 on the base line; drive a nail in each of these points to attach a string; fasten the string at 2 and carry it around the pencil at *c* and make fast at point 1 on the opposite side; now draw the pencil from *c* to *a*, keeping the string tight, and it will describe the arch; then reverse the string for other side.

AT POINT *c* ON THE LINE *ab* TO DRAW TWO ARCS OF CIRCLES TANGENT TO *ab* AND THE TWO PARALLELS *ah* AND *be* FORMING AN ARCH.—Make *ad*, Fig. 325, equal to *ac* and *be* equal to *bc*; draw *cf* at right angles to *ab* and *dg* at right angles to *ah*; with *g* as centre and radius *gd* draw the arc *dc*; draw *ef* at right angles to *be*; with *f* as centre and *fc* as radius draw the arc *ce*, completing the arch.

TO SPACE THE KERFING OF MOULDINGS, ETC.—Strike a circle of the same dimensions as that which it is desired to spring the moulding around; take a piece of the moulding and make a kerf in it and place the moulding across the circle as shown by Fig. 326, with the kerf at the centre; now hold that part

of the moulding marked *A* solid and bend the part marked *B* until the kerf or saw cut comes together. The distance the piece

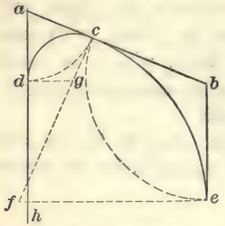


FIG. 325.

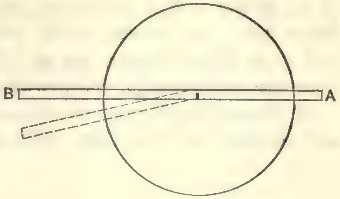


FIG. 326.

of moulding *B* has moved on the circle will be the distance apart to space the kerfs.

TO LAY OUT AN ARCH OR CURVE SIMILAR TO AN ELLIPSE, BUT WHOSE AXES DO NOT STAND AT RIGHT ANGLES.—Draw a parallelogram whose sides equal the axis, as *A*, *B*, *C*, and *D*, Fig. 327; now draw the two centre lines *EF* and *GH*;

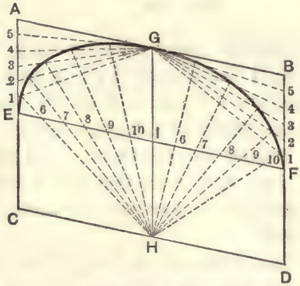


FIG. 327.

divide *AE* and *BF* into any number of equal parts, as 1, 2, 3, etc.; then divide *E*1 and 1*F* into the same number of parts and draw lines radiating from *G* to points 1, 2, 3, etc.; then draw lines radiating from *H* through points 6, 7, 8 etc., to strike the lines radiating from *G*, and through these intersections draw the curve as shown.

WHEN ANY THREE POINTS ARE GIVEN, TO DRAW A CIRCLE WHOSE CIRCUMFERENCE SHALL STRIKE EACH OF THE THREE POINTS.—With *a*, *b*, and *c* as the points, Fig. 328, join *a* and *b*

and *a* and *c* together, and draw lines at right angles from the centre of *ab* and *ac*, bisecting at *d*, which is the centre of the circle, and *da* the radius.

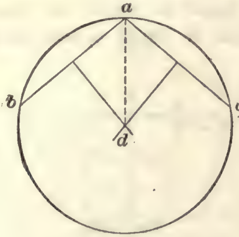


FIG. 328.

TO FIND THE CENTRE OF A CIRCLE.—Take any three points on the circumference and join them, as *a*, *b*, *c*, Fig. 329; then

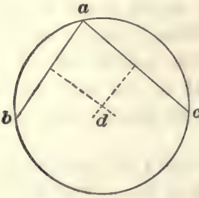


FIG. 329.

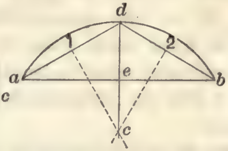


FIG. 330.

draw lines at right angles from the centre of *ab* and *ac* and the bisecting point *d* is the centre.

TO FIND THE DIAMETER OR RADIUS OF A CIRCLE WHEN THE CHORD AND RISE OF AN ARC ARE GIVEN.—Draw the chord as

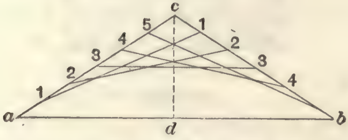


FIG. 331.

ab, then the rise *de*, Fig. 330; then connect *ad* and *db*; then draw lines 1*c* and 2*c* at right angles, and from the centre of

ad and *db*, until they intersect at *c*, which is the centre and *cd* the radius.

To Draw an Arc by Intersecting Lines when the Chord and Rise are Given.—Draw the chord as *ab*, Fig. 331; then draw *cd* equal to twice the rise, divide *ac* and *cb* into the same number of equal spaces and draw the lines as shown.

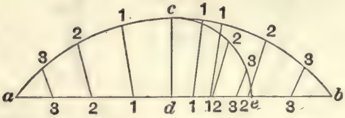


Fig. 332.

To Draw an Arc by Bending a Lath or Strip.—Let *ab* be the span and *cd* the rise, Fig. 332; with *cd* as radius and *d* as centre, draw the quarter-circle *ce*; now divide *ce* and *ed* into the same number of equal parts, as 1, 2, 3, etc.; now divide *db* and *da* into as many equal parts as *de*; now connect 1, 2, 3 on the quarter-circle and 1, 2, 3 on *de*, as shown; now draw lines from the points on *ad* and *db*, at the same angle and equal in length to the ones on the quarter-circle, as 1 1, 2 2, etc.; drive nails in these points and bend the strips around.

When the Span and Rise of an Arc are Given, to Draw the Curve.—Draw the span *ab* and rise *c*, Fig. 333; then, with

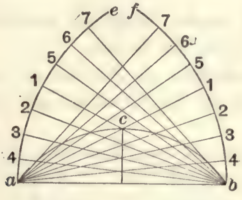


Fig. 333.

a and *b* as centres and *ab* as radius, draw arcs *ae* and *bf*; now draw lines from *a* and *b* through *c* until they strike *ae* and *bf*, as *a*1 and *b*1; divide *a*1 on *ae* and *b*1 on *bf* into any number of equal spaces, as 1, 2, 3, etc.; make 5, 6, 7 equally distant

and draw the lines as shown; draw the curve through the intersections as shown.

When the Chord and Rise of an Arc are Given, to Draw the Arc. — Take two strips and joint the edges

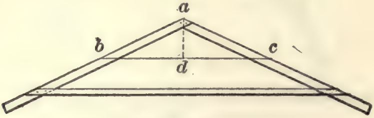


Fig. 334.

straight and make a frame, as shown in Fig. 334; *bc* is the chord and *ad* the rise of the arc. Drive a nail in the floor or drawing-board on the outside edge of the frame at *b* and

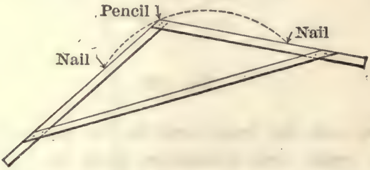


Fig. 335.

another one at *c*; then place the pencil at the point of the frame, *a*, and slide the frame around, keeping it tight against the nails, when the pencil will describe the curve, as shown in Fig. 335.

When the Chord and Rise of an Arc are Given, to Find the Radius.—Square one-half the chord, divide this product by the rise and to this answer add the rise and divide by 2; the answer is the radius. In Fig. 336, one-half the chord is 4, which squared equals 16, which divided by the rise equals $5\frac{1}{3}$, to which add the rise, equals $8\frac{1}{3}$, which divided by 2 equals $4\frac{1}{6}$, the radius.

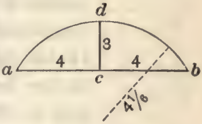


Fig. 336.

Laying Out Mansard and Gambrel Roofs.—To proportion a mansard or gambrel roof, draw a half-circle to a scale using the width of the building as the diameter, then draw the two slopes of the roof so that they intersect on the circle, as shown by Fig. 337.

Laying Out Circle Heads in Circle Walls.—This can be done with lines and circles, but the quickest way for the work-

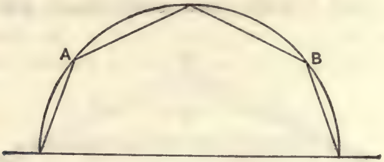


Fig. 337.

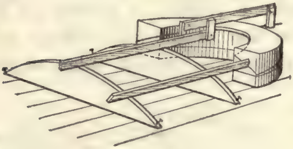
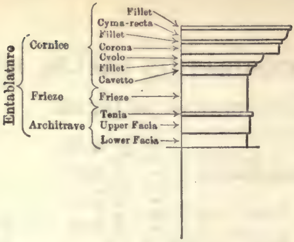


Fig. 338.

man is to cut out the head-piece to the desired circle for the frame; then make two templates equal to the circle of the wall and tack them on the drawing-board or floor, as shown by Fig. 338; now with a couple of straight-edges and pencil mark out the circle of the wall by sliding the strips over the templates.

Fig. 339.

To Lay Out Entasis of Columns, etc.—Draw length of column, as AB, Fig. 339; then AC, the radius of the column at the bottom, and DB, the radius of the column at the top; now describe the quarter-circle CE, and let fall the perpendicular DF. Divide the length of the column into spaces equal to the bottom radius, spacing from E as G, H, I, and J; divide the arc CF into the same number of equal spaces; now draw lines from the points on the centre line and at right angles to it, as $E6$, $G7$, etc., and draw perpendicular lines from points 1, 2, etc., on the arc to strike the lines from the centre line, as shown at 6, 7, 8, etc., and through these points draw the curve. Fig. 339 is drawn with considerable swell, so that the lines can be seen more plainly.



Names of Parts of an Entablature.

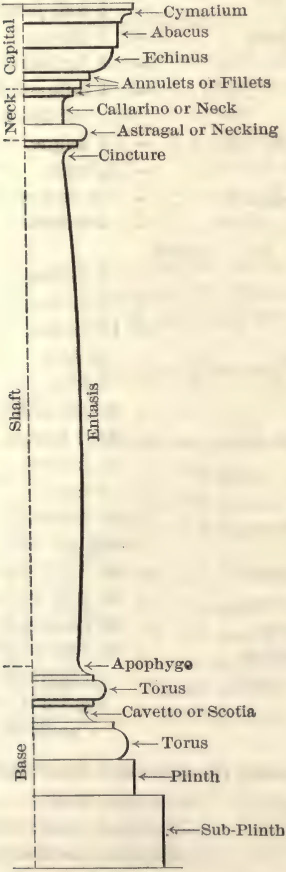


Fig. 340.—Names of Parts of a Column.

MENSURATION TABLES, ETC.

LINEAR MEASURE.

1 hair's breadth	=	$\frac{1}{48}$ inch.
3 barleycorns (lengthwise)	=	1 inch.
7.92 inches	=	1 link.
12 inches	=	1 foot = 0.3048 metre.
3 feet	=	1 yard = 0.91438 metre.
$5\frac{1}{2}$ yards	=	1 rod, perch, or pole.
4 poles or 100 links	=	1 chain.
10 chains	=	1 furlong.
8 furlongs	=	1 mile = 1.6093 kilometres = 5280 ft.
3 miles (nautical)	=	1 league.
1 line	=	$\frac{1}{12}$ inch.
1 nail (cloth measure)	=	$2\frac{1}{4}$ inches.
1 palm	=	3 inches.
1 hand (used for height of horses)	=	4 inches.
1 span	=	9 inches.
1 cubit	=	18 inches.
1 pace (military)	=	$2\frac{1}{2}$ feet.
1 pace (common)	=	3 feet.
1 Scotch ell	=	37.06 inches.
1 vara (Spanish)	=	33.3 inches.
1 English ell	=	45 inches.
1 fathom	=	6 feet.
1 cable's length	=	120 fathoms.
1 "knot"	=	6082.66 feet.
1 degree of equator	=	69.1613 statute miles.
1 degree of meridian	=	69.046 statute miles
1 degree of equator	=	60 geographical miles.
1 degree of meridian	=	59.899 geographical miles.
1.1527 statute miles	=	1 geographical mile.
6086.07 feet	=	1 minute of longitude = 1 nautical mile.

SQUARE OR SURFACE MEASURE.

144 square inches	=	1 square foot.
9 square feet	=	1 square yard = 1296 square inches.
100 square feet	=	1square (builders' measure).

LAND MEASURE.

$30\frac{1}{4}$ square yards........	= 1 square rod.
40 square rods.........	= 1 square rood = 1210 square yards.
4 square roods........	= 1 acre = 4840 square yards.
640 acres................	= 1 square mile.
208.71 feet square.......	= 1 acre.
1 square mile..........	= 1 section of land.
160 acres...............	= $\frac{1}{4}$ section of land.

CUBIC MEASURE.

1728 cubic inches...........	= 1 cubic foot.
27 cubic feet.............	= 1 cubic yard.
128 cubic feet.............	= 1 cord.
40 cubic feet.............	= 1 American shipping ton.
42 cubic feet.............	= 1 British shipping ton.
108 cubic feet.............	= 1 stack of wood.
24.75 cubic feet of stone......	= 1 perch.

Note.—Custom has made the number of feet in a perch vary in different localities. For instance, in Philadelphia a perch is 22 cubic feet, while in some of the New England States it is 16.5 cubic feet.

A ton, in computing the tonnage of vessels, is 100 cubic feet of their internal space.

AVOIRDUPOIS WEIGHT (ORDINARY COMMERCIAL WEIGHT).

16 drams........... =	1 ounce, oz.
16 ounces........... =	1 pound, lb.
28 lbs. (old)......... =	1 quarter, qr.
4 quarters (old) / 100 lbs., pounds .. =	1 hundredweight.
20 hundredweight ... =	1 ton.
100 pounds.......... =	1 cental.
175 troy pounds...... =	144 avoirdupois.
1 troy pound....... =	5760 grains.
1 avoirdupois pound =	7000 grains.

Avoirdupois weight is used to weigh all coarse articles, as hay, meat, fish, potash, groceries, flax, butter, cheese, etc., and metals, except precious metals. Formerly the usual custom was to allow 112 pounds for a hundredweight and 28 pounds for a

quarter, but this practice has very nearly passed away. The custom-house still adheres to the old usage.

APOTHECARIES' MEASURE—LIQUID.

60 minims or drops, m.,	=1 fluid drachm.
8 fluid drachms.	=1 fluid ounce.
16 fluid ounces	=1 pint (octarius).
8 pints.	=1 gallon (congius).

These apothecarie ' weights and measures are used by apothecaries and physicians in compounding medicines, but drugs and medicines are bought and sold by avoirdupois weight.

The standard avoirdupois pound is the weight of 27.7015 cubic inches of distilled water weighed in air at 39.1°, the barometer at 30 inches.

APOTHECARIES' WEIGHT—DRY.

20 grains. .	=1 scruple.
3 scruples	=1 dram.
8 drams. .	=1 ounce.
12 ounces	=1 pound.

LIQUID OR WINE MEASURE.

4	gills.	=1 pint, pt.
2	pints.	=1 quart, qt.
4	quarts	=1 gallon, gal.
42	gallons.	=1 tierce.
$1\frac{1}{2}$	tierces or 63 gallons. . . .	=1 hogshead, hhd.
84	gallons.	=1 puncheon.
$1\frac{1}{2}$	puncheons or 126 gallons	=1 pipe.
2	pipes.	=1 tun.
231	cubic inches.	=1 gallon.
10	gallons.	=1 anker.
18	"	=1 runlet.
$31\frac{1}{2}$	"	=1 barrel.

This measure is used to measure water, wine, spirits, cider, oil, honey, etc. In London the gill is usually called a quartern.

ALE OR BEER MEASURE.

2	pints	=1 quart.
4	quarts	=1 gallon.
9	gallons	=1 firkin.
2	firkins	=1 kilderkin.
2	kilderkins	=1 barrel.
1½	barrels	=1 hogshead.
1⅓	hogsheads	=1 puncheon.
1½	puncheons	=1 butt.

Used to measure beer, ales, porter, etc. An ale gallon measures 282 cubic inches.

ENGLISH WINE MEASURE.

18	U. S. gallons	=1 runlet.
25	English gallons	=1 tierce.
42	U. S. gallons	
7½	English gallons	=1 firkin of beer.
4	firkins	=1 barrel.
52¼	English gallons	=1 hogshead.
63	U. S. gallons	

DRY MEASURE.

2 pints	=1 quart	= 67.2	cubic inches.
4 quarts	=1 gallon	= 288.8	" "
2 gallons	=1 peck	= 537.6	" "
4 pecks	=1 bushel	=2150.42	" "
36 bushels	=1 chaldron	= 57.244	" feet.
4 bushels (in England)	=1 coon.		
2 coons " "	=1 quarter.		
5 quarters " "	=1 wey.		
2 weys " "	=1 last.		

A gallon, dry measure, measures 268⅘ cubic inches.

SURVEYORS' SQUARE MEASURE.

625	square links	=1 square rod, sq. rd.
16	" rods	=1 " chain, sq. ch.
10	" chains	=1 acre, A.
640	acres	=1 square mile, sq. mi.

36 square miles or 6 miles square = 1 township, tp.

SURVEYORS' LONG MEASURE.

7.92 inches . .	=1 link.
25 links. . . .	=1 pole.
100 links. . . .	=1 chain.
10 chains. .	=1 furlong.
8 furlongs	=1 mile.

Used by surveyors, civil engineers, etc., in measuring distances.

MEASURE OF TIME.

60 seconds, sec.	=1 minute, min.
60 minutes.	=1 hour, hr.
24 hours.	=1 day, dy
7 days.	=1 week, wk.
2 weeks.	=1 fortnight.
4 weeks.	=1 month, mo.
13 months 1 day 6 hrs.	=1 Julian year.
365 days 6 hours.	=1 Julian year.
366 days.	=1 leap year.
12 calendar months . .	=1 year.

Used for computing time.

CIRCULAR MEASURE.

60 seconds, ″. .	=1 minute, ′.
60 minutes. . . .	=1 degree, °.
30 degrees. . . .	=1 sign, s.
90 degrees. . . .	=1 quadrant.
12 signs	=a circle.
4 quadrants 360 degrees . .	=a circumference of a circle.

Used in measuring latitude, longitude, etc.

TROY WEIGHT.

Used in Weighing Gold or Silver.

24 grains.	=1 pennyweight.
20 pennyweights	=1 ounce.
12 ounces.	=1 pound.

A carat of the jewellers, for precious stones, is, in the United States, 3.2 grains; in London, 3.17 grains; in Paris 3.18 grains are divided into 4 jewellers' grains. In troy, apothecaries', and avoirdupois weights the grain is the same.

MEASURES OF VALUE.

U. S. Standard.

10 mills. . = 1 cent.
10 cents. . = 1 dime.
10 dimes = 1 dollar.
10 dollars = 1 eagle.

The standard of gold and silver is 900 parts of pure metal and 100 parts of alloy to 1000 parts of coin.

WEIGHT OF COIN.

Double eagle.	= 516 troy grains.
Eagle.	= 258 troy grains.
Dollar (gold).	= 25.8 troy grains.
Dollar (silver).	= 412.5 troy grains.
Half dollar.	= 192 troy grains.
5-cent piece (nickel)	= 77.16 troy grains.
3-cent piece (nickel)	= 30 troy grains.
Cent (copper).	= 48 troy grains.

NUMBER OF ENGLISH OR UNITED STATES YARDS IN MILES OF DIFFERENT NATIONS.

Name.	Yards.	Name.	Yards.
Arabian	2,148	Luthenian	9,784
Bohemian	10,187	Oldenburg	10,820
Brebant	6,082	Persian (paisang)	6,082
Burgundy	6,183	Polish (long)	8,101
Chinese (Hls)	682	Polish (short)	6,095
Dutch (Ure)	6,395	Portuguese (leguos)	6,760
Danish	8,244	Prussian	8,498
English (U. S.)	1,760	Roman (modern)	2,035
English (geographical)	2,025	Roman (ancient)	1,613
Flemish	6,869	Russian (verst)	1,167
German (geographical)	8,100	Saxon	9,905
Hamburg	8,244	Scotch	1,984
Hanover	11,559	Silesian	7,083
Hesse	10,547	Spanish (leguas)	4,630
Hungarian	9,113	Spanish (com.)	7,416
French (art leagues)	4,860	Swiss	9,166
French (marine)	6,075	Swedish	11,704
Legal Le'g'e (2000 toises)	4,263	Turkey	1,821
Irish	3,338	Tuscan	1,808
Italian	2,025	Vienna (post mile)	8,296

TABLE OF MISCELLANEOUS WEIGHTS.

14 pounds	=1 stone (horseman's weight).
56 pounds	=1 firkin of butter.
64 pounds	=1 firkin of soft soap.
112 pounds	=1 barrel of raisins.
256 pounds	=1 pack of soft soap.
196 pounds	=1 barrel of flour.
200 pounds	=1 barrel of beef, pork, or fish.
280 pounds	=1 barrel of salt, New York.
22 stones (301 lbs.)	=1 sack of wool.
17 stones 2 lbs. (240 lbs.)	=1 pack of wool.
60 pounds	=1 truss of hay (new).
50 pounds	=1 truss of hay (old).
40 pounds	=1 truss of straw.
400 pounds	=1 bale of cotton.
100 pounds	=1 quintal of fish.

NUMBER OF POUNDS TO BUSHEL.

Recognized by the laws of the United States.

Wheat	60
Shelled corn	56
Corn in ear	70
Rye	56
Oats	32
Barley	48
Irish potatoes	60
Sweet potatoes	50
White beans	60
Castor-beans	46
Clover-seed	60
Timothy-seed	45
Flaxseed	56
Hempseed	44
Peas	60
Blue-grass seed	14
Buckwheat	52
Dried peaches	33
Dried apples	24
Onions	57
Salt	50
Stone coal	80
Coke	46
Malt	84
Bran	30
Plastering hair	88
Turnips	57
Unslacked lime	80
Corn-meal	50
Fine salt	62
Hungarian grass-seed	48
Ground peas	24
Onion-sets	14
Onion tops	25
Onion bottoms	35

METRIC SYSTEM OF WEIGHTS AND MEASURES.

The Metric System was legalized in the United States on July 28, 1866, when Congress enacted as follows:

"The tables in the schedule hereto annexed shall be recognized in the construction of contracts, and in all legal proceedings, as establishing, in terms of the weights and measures now in use in the United States, the equivalents of the weights and measures expressed therein in terms of the metric system, and the tables may lawfully be used for computing, determining, and expressing in customary weights and measures the weights and measures of the metric system."

MEASURE OF LENGTH

10,000 metres	= 1 myriametre.	1 metre	= 1 metre.
1,000 "	= 1 kilometre.	.1 "	= 1 decimetre.
100 "	= 1 hectometre.	.01 "	= 1 centimetre.
10 "	= 1 decametre.	.001 "	= 1 millimetre.

MEASURE OF SURFACE.

10,000 sq. metres	= 1 hectare.	Hectare	= 2.471 acres.
100 " "	= 1 are.	Are	= ·119.6 square yards.
1 " "	= 1 centare.	Centare	= 1550 sq. ins.

MEASURE OF LENGTH.

Myriametre	= 6.2137 miles.	Metre	= 39.37 inches.
Kilometre	= 0.62137 mile = 3280 feet 10 inches.	Decimetre	= 3.937 inches.
Hectometre	= 328 feet 1 inch.	Centimetre	= .3937 inch.
Decametre	= 393.7 inches.	Millimetre	= .0394 inch.

MEASURES OF CAPACITY.

1,000 litres	= 1 kilolitre or 1 cubic metre.
100 "	= 1 hectolitre or 0.1 cubic metre.
10 "	= 1 decalitre or 10 cubic decimetres.
1 litre	= 1 litre or 1 cubic decimetre.
.1 "	= 1 decilitre or 0.1 cubic decimetre.
.01 "	= 1 centilitre or 10 cubic centimetres.
.001 "	= 1 millilitre or 0.1 cubic centimetre.

EQUIVALENTS OF DENOMINATIONS IN USE.

DRY MEASURE.

1 kilolitre	=1.308 cu. yds.
1 hectolitre	=2 bu., 3.35 pks.
1 decalitre	=9.08 quarts.
1 litre	= .908 quart.
1 decilitre	=6.1022 cu. in.
1 centilitre	= .6102 cu. in.
1 millilitre	= .061 cu. in.

LIQUID MEASURE.

1 kilolitre	=264.17 gal.
1 hectolitre	= 26.417 "
1 decalitre	= 2.6417 "
1 litre	= 1.0567 qt.
1 decilitre	= .845 gill.
1 centilitre	= .368 fluid oz.
1 millilitre	= .27 fluid dm.

WEIGHTS.

1,000,000	grains	=1 millier or tonneau.
100,000	"	=1 quintal.
10,000	"	=1 myriagram.
1,000	"	=1 kilogram.
100	"	=1 hectogram.
10	"	=1 decagram.
1	gr.	=1 gram.
.1	"	=1 decigram.
.01	"	=centigram.
.001	"	=milligram.

1 millier	=2,204.6	lbs.	avoirdupois.
1 quintal	= 220.46	"	"
1 myriagram	= 22.046	"	"
1 kilogram	= 2.2046	"	"
1 hectogram	= 3.5274	ounces	"
1 decagram	= .3527	ounce	"
1 gram	= 15.432	grains	"
1 decigram	= 1.5432	"	"
1 centigram	= .1543	grain	"
1 milligram	= .0154	"	"

In the metric system the meter is the base of all weights and measures which it employs. The meter is one-ten-millionth part of the distance measured on a meridian of the earth from the equator to the pole, and equals about 39.37 inches, or nearly 3 ft. 3⅜ inches.

COMMON WEIGHTS AND MEASURES AND THEIR METRIC EQUIVALENTS.

An inch = 2.54 centimetres.
A foot = .3048 metre.
A yard = .9144 metre.
A rod = 5.029 metres.
A mile = 1.6093 kilometres.
A square inch = 6.452 square centimetres.
A square foot = .0929 sq. m.
A square yard = .8361 sq. m.
An acre = .4047 hectare.
A square mile = 259 hectares.
A cubic foot = .02832 cu. m.
A cubic yard = .7646 cu. m.
A cord = 3.624 steres.
A liquid quart = .9465 litre.
A gallon = 3.786 litres.
A dry quart = 1.101 litres
A peck = 8.811 litres.
A bushel = 35.24 litres.
An ounce avoirdupois = 28.35 grams.
A pound avoirdupois = .4336 kilogram.
A ton = .9072 tonneau.
A grain troy = .0648 gram.
An ounce troy = 31.104 grms.
A pound troy = .3732 kgrm.

INTERCHANGEABLE TABLES BETWEEN UNITED STATES AND METRIC SYSTEMS.

1 Metre = 39.37 Inches. (Act of Congress.)

Long Measure.

Number.	64ths of an Inch to Millimetres.	Millimetres to 64ths of an Inch.	Inches to Centimetres.	Centimetres to Inches.
1	0.3969	2.5197	2.54	0.3937
2	0.7938	5.0394	5.08	0.7874
3	1.1906	7.5590	7.62	1.1811
4	1.5875	10.0787	10.16	1.5748
5	1.9844	12.5984	12.70	1.9685
6	2.3813	15.1181	15.24	2.3622
7	2.7781	17.6378	17.78	2.7559
8	3.1750	20.1574	20.32	3.1496
9	3.5719	22.6771	22.86	3.5433

Number.	Metres to Feet.	Feet to Metres.	Kilometres to Miles.	Miles to Kilometres.
1	3.2808	0.3048	0.62137	1.60935
2	6.5617	0.6096	1.24274	3.21869
3	9.8425	0.9144	1.86411	4.82804
4	13.1233	1.2192	2.48548	6.43739
5	16.4042	1.5240	3.10685	8.04674
6	19.6850	1.8288	3.72822	9.65608
7	22.9658	2.1336	4.34959	11.26543
8	26.2467	2.4384	4.97096	12.87478
9	29.5275	2.7432	5.59233	14.48412

Square Measure.

Number.	Square Inches to Square Centimetres.	Square Centimet's to Square Inches.	Square Feet to Square Metres.	Square Metres to Square Feet.	Square Yards to Square Metres.	Square Metres to Square Yards.
1	6.4516	0.155	0.0929	10.7639	0.8361	1.196
2	12.9032	0.310	0.1858	21.5278	1.6722	2.392
3	19.3548	0.465	0.2787	32.2917	2.5084	3.588
4	25.8064	0.620	0.3716	43.0556	3.3445	4.784
5	32.2581	0.775	0.4645	53.8194	4.1806	5.980
6	38.7097	0.930	0.5574	64.5833	5.0167	7.176
7	45.1613	1.085	0.6503	75.3472	5.8528	8.372
8	51.6129	1.240	0.7432	86.1111	6.6890	9.568
9	58.0645	1.395	0.8361	96.8750	7.5251	10.764

INTERCHANGEABLE TABLES BETWEEN UNITED STATES AND METRIC SYSTEMS.

Square Measure.

Number.	Acres to Hectares.	Hectares to Acres.	Square Miles to Square Kilometres.	Square Kilometres to Square Miles.	Square Miles to Hectares.	Hectares to Square Miles.
1	0.4047	2.471	2.59	0.3861	259.00	0.00386
2	0.8094	4.942	5.18	0.7722	518.00	0.00772
3	1.2141	7.413	7.77	1.1583	777.01	0.01158
4	1.6188	9.884	10.36	1.5444	1036.01	0.01544
5	2.0235	12.355	12.95	1.9305	1295.02	0.01930
6	2.4282	14.826	15.54	2.3166	1554.02	0.02317
7	2.8329	17.297	18.13	2.7027	1813.03	0.02703
8	3.2376	19.768	20.72	3.0887	2072.03	0.03089
9	3.6422	22.239	23.31	3.4748	2331.04	0.03475

1 Kilogram = 2.2046 Pounds. (Act of Congress.)

Weights.

Number.	Kilograms to Ounces Troy.	Troy Ounces to Grams.	Grains to Milligrams.	Grams to Grains.	Gross Tons to Metric Tons.	Metric Tons to Gross Tons.
1	32.1507	31.1035	64.8004	15.432	1.0161	0.9842
2	64.3015	62.2070	129.6008	30.864	2.0321	1.9684
3	96.4522	93.3104	194.4012	46.296	3.0482	2.9526
4	128.6030	124.4139	259.2017	61.728	4.0642	3.9368
5	160.7537	155.5174	324.0021	77.160	5.0803	4.9210
6	192.9045	186.6209	388.8025	92.592	6.0963	5.9052
7	225.0552	217.7244	453.6029	108.024	7.1124	6.8894
8	257.2059	248.8278	518.4033	123.456	8.1285	7.8736
9	289.3567	279.9313	583.2037	138.888	9.1445	8.8578

Number.	Avoirdupois Ounces to Grams.	Kilograms to Ounces Avoirdupois.	Avoirdupois Pounds to Kilograms.	Kilograms to Pounds Avoirdupois.	Net Tons to Metric Tons.	Metric Tons to Net Tons.
1	28.3495	35.274	0.4536	2.2046	0.9072	1.1023
2	56.6990	70.548	0.9072	4.4092	1.8144	2.2046
3	85.0485	105.822	1.3608	6.6138	2.7216	3.3069
4	113.3980	141.096	1.8144	8.8184	3.6288	4.4092
5	141.7475	176.370	2.2680	11.0230	4.5360	5.5115
6	170.0970	211.644	2.7216	13.2276	5.4432	6.6138
7	198.4464	246.918	3.1752	15.4322	6.3504	7.7161
8	226.7959	282.192	3.6288	17.6368	7.2576	8.8184
9	255.1454	317.466	4.0824	19.8414	8.1647	9.9207

INTERCHANGEABLE TABLES BETWEEN UNITED STATES AND METRIC SYSTEMS.

1 Litre = { 1.0567 Quarts—Liquid Measure. / 0.908 Quart —Dry Measure. } (Act of Congress.)

Liquid and Dry Measure.

Number.	Litres to Quarts.		Quarts to Litres.		Litres to Gallons, Liquid.	Gallons to Litres, Liquid.
	Liquid.	Dry.	Liquid.	Dry.		
1	1.0567	0.908	0.9463	1.1013	0.2642	3.7854
2	2.1134	1.816	1.8927	2.2026	0.5284	7.5707
3	3.1701	2.724	2.8390	3.3040	0.7925	11.3561
4	4.2268	3.632	3.7854	4.4053	1.0567	15.1415
5	5.2835	4.540	4.7317	5.5066	1.3209	18.9268
6	6.3402	5.448	5.6781	6.6079	1.5851	22.7122
7	7.3969	6.356	6.6244	7.7093	1.8492	26.4976
8	8.4536	7.264	7.5707	8.8106	2.1134	30.2830
9	9.5103	8.172	8.5171	9.9119	2.3776	34.0683

Number.	Cubic Metres to Gallons, Liquid.	Gallons to Cubic Metres, Liquid.	Hectolitres to Bushels, Dry.	Bushels to Hectolitres, Dry.
1	264.17	0.0038	2.8375	0.3524
2	528.34	0.0076	5.6750	0.7048
3	792.51	0.0114	8.5125	1.0573
4	1056.68	0.0151	11.3500	1.4097
5	1320.85	0.0189	14.1875	1.7621
6	1585.02	0.0227	17.0250	2.1145
7	1849.19	0.0265	19.8625	2.4670
8	2113.36	0.0303	22.7000	2.8194
9	2377.53	0.0341	25.5375	3.1718

Cubic, Horse-power, and Ton Measures.

Number.	Cubic Centimetres to Cubic Inches.	Cubic Inches to Cubic Centimetres.	Cubic Metres to Cubic Feet.	Cubic Feet to Cubic Metres.	Cubic Metres to Cubic Yards.	Cubic Yards to Cubic Metres.
1	0.061	16.3934	35.316	0.0283	1.308	0.7645
2	0.122	32.7869	70.632	0.0566	2.616	1.5291
3	0.183	49.1803	105.948	0.0849	3.924	2.2936
4	0.244	65.5738	141.264	0.1133	5.232	3.0581
5	0.305	81.9672	176.580	0.1416	6.540	3.8226
6	0.366	98.3607	211.896	0.1699	7.848	4.5872
7	0.427	114.7541	247.212	0.1982	9.156	5.3517
8	0.488	131.1475	282.528	0.2265	10.464	6.1162
9	0.549	147.5410	317.844	0.2548	11.772	6.8807

INTERCHANGEABLE TABLES BETWEEN UNITED STATES AND METRIC SYSTEMS.

Number.	Horse-power Metric to U. S.	Horse-power U. S. to Metric.	Foot-pounds to Kilogram-metres.	Kilogram-metres to Foot-pounds.	Gross Tons per Sq. Ft. to Metric Tons per Sq. Metre.	Metric Tons per Sq. Metre to Gross Tons per Sq. Foot.
1	0.986	1.014	0.1383	7.2329	10.937	0.091
2	1.973	2.028	0.2765	14.4659	21.873	0.183
3	2.959	3.042	0.4148	21.6988	32.810	0.274
4	3.945	4.056	0.5530	28.9317	43.747	0.366
5	4.932	5.069	0.6913	36.1646	54.684	0.457
6	5.918	6.083	0.8295	43.3976	65.620	0.549
7	6.904	7.097	0.9678	50.6305	76.557	0.640
8	7.890	8.111	1.1061	57.8634	87.494	0.731
9	8.877	9.125	1.2443	65.0963	98.431	0.823

Miscellaneous.

Number.	Kilo. per Metre to Pounds per Foot.	Pounds per Foot to Kilo. per Metre.	Kilo. per Square Metre to Pounds per Square Foot.	Pounds per Square Foot to Kilo. per Square Metre.
1	0.6720	1.4882	0.2048	4.8825
2	1.3439	2.9764	0.4096	9.7649
3	2.0159	4.4645	0.6144	14.6474
4	2.6879	5.9527	0.8193	19.5299
5	3.3598	7.4409	1.0241	24.4123
6	4.0318	8.9291	1.2289	29.2948
7	4.7037	10.4172	1.4337	34.1773
8	5.3757	11.9054	1.6385	39.0597
9	6.0477	13.3936	1.8433	43.9422

Number.	Kilo. per Cubic Metre to Pounds per Cubic Foot.	Pounds per Cubic Foot to Kilo. per Cubic Metre.	Kilo. per Square Centimetre to Pounds per Square Inch.	Pounds per Square Inch to Kilo. per Square Centimetre.
1	0.0624	16.0192	14.2232	0.0703
2	0.1248	32.0385	28.4465	0.1406
3	0.1873	48.0577	42.6697	0.2109
4	0.2497	64.0769	56.8929	0.2812
5	0.3121	80.0962	71.1161	0.3515
6	0.3745	96.1154	85.3394	0.4218
7	0.4370	112.1346	99.5626	0.4922
8	0.4994	128.1539	113.7858	0.5625
9	0.5618	144.1731	128.0090	0.6328

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000.

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000 × Recip.	No. = Diameter.	
							Circum.	Area.
1	1	1	1.0000	1.0000	0.00000	1000.000	3.142	0.7854
2	4	8	1.4142	1.2599	0.30103	500.000	6.283	3.1416
3	9	27	1.7321	1.4422	0.47712	333.333	9.425	7.0686
4	16	64	2.0000	1.5874	0.60206	250.000	12.566	12.5664
5	25	125	2.2361	1.7100	0.69897	200.000	15.708	19.6350
6	36	216	2.4495	1.8171	0.77815	166.667	18.850	28.2743
7	49	343	2.6458	1.9129	0.84510	142.857	21.991	38.4845
8	64	512	2.8284	2.0000	0.90309	125.000	25.133	50.2655
9	81	729	3.0000	2.0801	0.95424	111.111	28.274	63.6173
10	100	1000	3.1623	2.1544	1.00000	100.000	31.416	78.5398
11	121	1331	3.3166	2.2240	1.04139	90.9091	34.558	95.0332
12	144	1728	3.4641	2.2894	1.07918	83.3333	37.699	113.097
13	169	2197	3.6056	2.3513	1.11394	76.9231	40.841	132.732
14	196	2744	3.7417	2.4101	1.14613	71.4286	43.982	153.938
15	225	3375	3.8730	2.4662	1.17609	66.6667	47.124	176.715
16	256	4096	4.0000	2.5198	1.20412	62.5000	50.265	201.062
17	289	4913	4.1231	2.5713	1.23045	58.8235	53.407	226.980
18	324	5832	4.2426	2.6207	1.25527	55.5556	56.549	254.469
19	361	6859	4.3589	2.6684	1.27875	52.6316	59.690	283.529
20	400	8000	4.4721	2.7144	1.30103	50.0000	62.832	314.159
21	441	9261	4.5826	2.7589	1.32222	47.6190	65.973	346.361
22	484	10648	4.6904	2.8020	1.34242	45.4545	69.115	380.133
23	529	12167	4.7958	2.8439	1.36173	43.4783	72.257	415.476
24	576	13824	4.8990	2.8845	1.38021	41.6667	75.398	452.389
25	625	15625	5.0000	2.9240	1.39794	40.0000	78.540	490.874
26	676	17576	5.0990	2.9625	1.41497	38.4615	81.681	530.929
27	729	19683	5.1962	3.0000	1.43136	37.0370	84.823	572.555
28	784	21952	5.2915	3.0366	1.44716	35.7143	87.965	615.752
29	841	24389	5.3852	3.0723	1.46240	34.4828	91.106	660.520
30	900	27000	5.4772	3.1072	1.47712	33.3333	94.248	706.858
31	961	29791	5.5678	3.1414	1.49136	32.2581	97.389	754.768
32	1024	32768	5.6569	3.1748	1.50515	31.2500	100.531	804.248
33	1089	35937	5.7446	3.2075	1.51851	30.3030	103.673	855.299
34	1156	39304	5.8310	3.2396	1.53148	29.4118	106.814	907.920
35	1225	42875	5.9161	3.2711	1.54407	28.5714	109.956	962.113
36	1296	46656	6.0000	3.3019	1.55630	27.7778	113.097	1017.88
37	1369	50653	6.0828	3.3322	1.56820	27.0270	116.239	1075.21
38	1444	54872	6.1644	3.3620	1.57978	26.3158	119.381	1134.11
39	1521	59319	6.2450	3.3912	1.59106	25.6410	122.522	1194.59
40	1600	64000	6.3246	3.4200	1.60206	25.0000	125.66	1256.64
41	1681	68921	6.4031	3.4482	1.61278	24.3902	128.81	1320.25
42	1764	74088	6.4807	3.4760	1.62325	23.8095	131.95	1385.44
43	1849	79507	6.5574	3.5034	1.63347	23.2558	135.09	1452.20
44	1936	85184	6.6332	3.5303	1.64345	22.7273	138.23	1520.53
45	2025	91125	6.7082	3.5569	1.65321	22.2222	141.37	1590.43
46	2116	97336	6.7823	3.5830	1.66276	21.7391	144.51	1661.90
47	2209	103823	6.8557	3.6088	1.67210	21.2766	147.65	1734.94
48	2304	110592	6.9282	3.6342	1.68124	20.8333	150.80	1809.56
49	2401	117649	7.0000	3.6593	1.69020	20.4082	153.94	1885.74

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
50	2500	125000	7.0711	3.6840	1.69897	20.0000	157.08	1963.50
51	2601	132651	7.1414	3.7084	1.70757	19.6078	160.22	2042.82
52	2704	140608	7.2111	3.7325	1.71600	19.2308	163.36	2123.72
53	2809	148877	7.2801	3.7563	1.72428	18.8679	166.50	2206.18
54	2916	157464	7.3485	3.7798	1.73239	18.5185	169.65	2290.22
55	3025	166375	7.4162	3.8030	1.74036	18.1818	172.79	2375.83
56	3136	175616	7.4833	3.8259	1.74819	17.8571	175.93	2463.01
57	3249	185193	7.5498	3.8485	1.75587	17.5439	179.07	2551.76
58	3364	195112	7.6158	3.8709	1.76343	17.2414	182.21	2642.08
59	3481	205379	7.6811	3.8930	1.77085	16.9422	185.35	2733.97
60	3600	216000	7.7460	3.9149	1.77815	16.6667	188.50	2827.43
61	3721	226981	7.8102	3.9365	1.78533	16.3934	191.64	2922.47
62	3844	238328	7.8740	3.9579	1.79239	16.1290	194.78	3019.07
63	3969	250047	7.9373	3.9791	1.79934	15.8730	197.92	3117.25
64	4096	262144	8.0000	4.0000	1.80618	15.6250	201.06	3216.99
65	4225	274625	8.0623	4.0207	1.81291	15.3846	204.20	3318.31
66	4356	287496	8.1240	4.0412	1.81954	15.1515	207.35	3421.19
67	4489	300763	8.1854	4.0615	1.82607	14.9254	210.49	3525.65
68	4624	314432	8.2462	4.0817	1.83251	14.7059	213.63	3631.68
69	4761	328509	8.3066	4.1016	1.83885	14.4928	216.77	3739.28
70	4900	343000	8.3666	4.1213	1.84510	14.2857	219.91	3848.45
71	5041	357911	8.4261	4.1408	1.85126	14.0845	223.05	3959.19
72	5184	373248	8.4853	4.1602	1.85733	13.8889	226.19	4071.50
73	5329	389017	8.5440	4.1793	1.86332	13.6986	229.34	4185.39
74	5476	405224	8.6023	4.1983	1.86923	13.5135	232.48	4300.84
75	5625	421875	8.6603	4.2172	1.87506	13.3333	235.62	4417.86
76	5776	438976	8.7178	4.2358	1.88081	13.1579	238.76	4536.46
77	5929	456533	8.7750	4.2543	1.88649	12.9870	241.90	4656.63
78	6084	474552	8.8318	4.2727	1.89209	12.8205	245.04	4778.36
79	6241	493039	8.8882	4.2908	1.89763	12.6582	248.19	4901.67
80	6400	512000	8 9443	4.3089	1.90309	12.5000	251.33	5026.55
81	6561	531441	9.0000	4.3267	1.90849	12.3457	254.47	5153.00
82	6724	551368	9.0554	4.3445	1.91381	12.1951	257.61	5281.02
83	6889	571787	9.1104	4.3621	1.91908	12.0482	260.75	5410.61
84	7056	592704	9.1652	4.3795	1.92428	11.9048	263.89	5541.77
85	7225	614125	9.2195	4.3968	1.92942	11.7647	267.04	5674.50
86	7396	636056	9.2736	4.4140	1.93450	11.6279	270.18	5808.80
87	7569	658503	9.3274	4.4310	1.93952	11.4943	273.32	5944.68
88	7744	681472	9.3808	4.4480	1.94448	11.3636	276.46	6082.12
89	7921	704969	9.4340	4.4647	1.94939	11.2360	279.60	6221.14
90	8100	729000	9.4868	4.4814	1.95424	11.1111	282.74	6361.73
91	8281	753571	9.5394	4.4979	1.95904	10.9890	285.88	6503.88
92	8464	778688	9.5917	4.5144	1.96379	10.8696	289.03	6647.61
93	8649	804357	9.6437	4.5307	1.96848	10.7527	292.17	6792.91
94	8836	830584	9.6954	4.5468	1.97313	10.6383	295.31	6939.78
95	9025	857375	9.7468	4.5629	1.97772	10.5263	298.45	7088.22
96	9216	884736	9.7980	4.5789	1.98227	10.4167	301.59	7238.23
97	9409	912673	9.8489	4.5947	1.98677	10.3093	304.73	7389.81
98	9604	941192	9.8995	4.6104	1.99123	10.2041	307.88	7542.96
99	9801	970299	9.9499	4.6261	1.99564	10.1010	311.02	7697.69

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
100	10000	1000000	10.0000	4.6416	2.00000	10.0000	314.16	7853.98
101	10201	1030301	10.0499	4.6570	2.00432	9.90099	317.30	8011.85
102	10404	1061208	10.0995	4.6723	2.00860	9.80392	320.44	8171.28
103	10609	1092727	10.1489	4.6875	2.01284	9.70874	323.58	8332.29
104	10816	1124864	10.1980	4.7027	2.01703	9.61538	326.73	8494.87
105	11025	1157625	10.2470	4.7177	2.02119	9.52381	329.87	8659.01
106	11236	1191016	10.2956	4.7326	2.02531	9.43396	333.01	8824.73
107	11449	1225043	10.3441	4.7475	2.02938	9.34579	336.15	8992.02
108	11664	1259712	10.3923	4.7622	2.03342	9.25926	339.29	9160.88
109	11881	1295029	10.4403	4.7769	2.03743	9.17431	342.43	9331.32
110	12100	1331000	10.4881	4.7914	2.04139	9.09091	345.58	9503.32
111	12321	1367631	10.5357	4.8059	2.04532	9.00901	348.72	9676.89
112	12544	1404928	10.5830	4.8203	2.04922	8.92857	351.86	9852.03
113	12769	1442897	10.6301	4.8346	2.05308	8.84956	355.00	10028.7
114	12996	1481544	10.6771	4.8488	2.05690	8.77193	358.14	10207.0
115	13225	1520875	10.7238	4.8629	2.06070	8.69565	361.28	10386.9
116	13456	1560896	10.7703	4.8770	2.06446	8.62069	364.42	10568.3
117	13689	1601613	10.8167	4.8910	2.06819	8.54701	367.57	10751.3
118	13924	1643032	10.8628	4.9049	2.07188	8.47458	370.71	10935.9
119	14161	1685159	10.9087	4.9187	2.07555	8.40336	373.85	11122.0
120	14400	1728000	10.9545	4.9324	2.07918	8.33333	376.99	11309.7
121	14641	1771561	11.0000	4.9461	2.08279	8.26446	380.13	11499.0
122	14884	1815848	11.0454	4.9597	2.08636	8.19672	383.27	11689.9
123	15129	1860867	11.0905	4.9732	2.08991	8.13008	386.42	11882.3
124	15376	1906624	11.1355	4.9866	2.09342	8.06452	389.56	12076.3
125	15625	1953125	11.1803	5.0000	2.09691	8.00000	392.70	12271.8
126	15876	2000376	11.2250	5.0133	2.10037	7.93651	395.84	12469.0
127	16129	2048383	11.2694	5.0265	2.10380	7.87402	398.98	12667.7
128	16384	2097152	11.3137	5.0397	2.10721	7.81250	402.12	12868.0
129	16641	2146689	11.3578	5.0528	2.11059	7.75194	405.27	13069.8
130	16900	2197000	11.4018	5.0658	2.11394	7.69231	408.41	13273.2
131	17161	2248091	11.4455	5.0788	2.11727	7.63359	411.55	13478.2
132	17424	2299968	11.4891	5.0916	2.12057	7.57576	414.69	13684.8
133	17689	2352637	11.5326	5.1045	2.12385	7.51880	417.83	13892.9
134	17956	2406104	11.5758	5.1172	2.12710	7.46269	420.97	14102.6
135	18225	2460375	11.6190	5.1299	2.13033	7.40741	424.12	14313.9
136	18496	2515456	11.6619	5.1426	2.13354	7.35294	427.26	14526.7
137	18769	2571353	11.7047	5.1551	2.13672	7.29927	430.40	14741.1
138	19044	2628072	11.7473	5.1676	2.13988	7.24638	433.54	14957.1
139	19321	2685619	11.7898	5.1801	2.14301	7.19424	436.68	15174.7
140	19600	2744000	11.8322	5.1925	2.14613	7.14286	439.82	15393.8
141	19881	2803221	11.8743	5.2048	2.14922	7.09220	442.96	15614.5
142	20164	2863288	11.9164	5.2171	2.15229	7.04225	446.11	15836.8
143	20449	2924207	11.9583	5.2293	2.15534	6.99301	449.25	16060.6
144	20736	2985984	12.0000	5.2415	2.15836	6.94444	452.39	16286.0
145	21025	3048625	12.0416	5.2536	2.16137	6.89655	455.53	16513.0
146	21316	3112136	12.0830	5.2656	2.16435	6.84932	458.67	16741.5
147	21609	3176523	12.1244	5.2776	2.16732	6.80272	461.81	16971.7
148	21904	3241792	12.1655	5.2896	2.17026	6.75676	464.96	17203.4
149	22201	3307949	12.2066	5.3015	2.17319	6.71141	468.10	17436.6

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
150	22500	3375000	12.2474	5.3133	2.17609	6.66667	471.24	17671.5
151	22801	3442951	12.2882	5.3251	2.17898	6.62252	474.38	17907.9
152	23104	3511808	12.3288	5.3368	2.18184	6.57895	477.52	18145.8
153	23409	3581577	12.3693	5.3485	2.18469	6.53595	480.66	18385.4
154	23716	3652264	12.4097	5.3601	2.18752	6.49351	483.81	18626.5
155	24025	3723875	12.4499	5.3717	2.19033	6.45161	486.95	18869.2
156	24336	3796416	12.4900	5.3832	2.19312	6.41026	490.09	19113.4
157	24649	3869893	12.5300	5.3947	2.19590	6.36943	493.23	19359.3
158	24964	3944312	12.5698	5.4061	2.19866	6.32911	496.37	19606.7
159	25281	4019679	12.6095	5.4175	2.20140	6.28931	499.51	19855.7
160	25600	4096000	12.6491	5.4288	2.20412	6.25000	502.65	20106.2
161	25921	4173281	12.6886	5.4401	2.20683	6.21118	505.80	20358.3
162	26244	4251528	12.7279	5.4514	2.20952	6.17284	508.94	20612.0
163	26569	4330747	12.7671	5.4626	2.21219	6.13497	512.08	20867.2
164	26896	4410944	12.8062	5.4737	2.21484	6.09756	515.22	21124.1
165	27225	4492125	12.8452	5.4848	2.21748	6.06061	518.36	21382.5
166	27556	4574296	12.8841	5.4959	2.22011	6.02410	521.50	21642.4
167	27889	4657463	12.9228	5.5069	2.22272	5.98802	524.65	21904.0
168	28224	4741632	12.9615	5.5178	2.22531	5.95238	527.79	22167.1
169	28561	4826809	13.0000	5.5288	2.22789	5.91716	530.93	22431.8
170	28900	4913000	13.0384	5.5397	2.23045	5.88235	534.07	22698.0
171	29241	5000211	13.0767	5.5505	2.23300	5.84795	537.21	22965.8
172	29584	5088448	13.1149	5.5613	2.23553	5.81395	540.35	23235.2
173	29929	5177717	13.1529	5.5721	2.23805	5.78035	543.50	23506.2
174	30276	5268024	13.1909	5.5828	2.24055	5.74713	546.64	23778.7
175	30625	5359375	13.2288	5.5934	2.24304	5.71429	549.78	24052.8
176	30976	5451776	13.2665	5.6041	2.24551	5.68182	552.92	24328.5
177	31329	5545233	13.3041	5.6147	2.24797	5.64972	556.06	24605.7
178	31684	5639752	13.3417	5.6252	2.25042	5.61798	559.20	24884.6
179	32041	5735339	13.3791	5.6357	2.25285	5.58659	562.35	25164.9
180	32400	5832000	13.4164	5.6462	2.25527	5.55556	565.49	25446.9
181	32761	5929741	13.4536	5.6567	2.25768	5.52486	568.63	25730.4
182	33124	6028568	13.4907	5.6671	2.26007	5.49451	571.77	26015.5
183	33489	6128487	13.5277	5.6774	2.26245	5.46448	574.91	26302.2
184	33856	6229504	13.5647	5.6877	2.26482	5.43478	578.05	26590.4
185	34225	6331625	13.6015	5.6980	2.26717	5.40541	581.19	26880.3
186	34596	6434856	13.6382	5.7083	2.26951	5.37634	584.34	27171.6
187	34969	6539203	13.6748	5.7185	2.27184	5.34759	587.48	27464.6
188	35344	6644672	13.7113	5.7287	2.27416	5.31915	590.62	27759.1
189	35721	6751269	13.7477	5.7388	2.27646	5.29101	593.76	28055.2
190	36100	6859000	13.7840	5.7489	2.27875	5.26316	596.90	28352.9
191	36481	6967871	13.8203	5.7590	2.28103	5.23560	600.04	28652.1
192	36864	7077888	13.8564	5.7690	2.28330	5.20833	603.19	28952.9
193	37249	7189057	13.8924	5.7790	2.28556	5.18135	606.33	29255.3
194	37636	7301384	13.9284	5.7890	2.28780	5.15464	609.47	29559.2
195	38025	7414875	13.9642	5.7989	2.29003	5.12821	612.61	29864.8
196	38416	7529536	14.0000	5.8088	2.29226	5.10204	615.75	30171.9
197	38809	7645373	14.0357	5.8186	2.29447	5.07614	618.89	30480.5
198	39204	7763392	14.0712	5.8285	2.29667	5.05051	622.04	30790.7
199	39601	7880599	14.1067	5.8383	2.29885	5.02513	625.18	31102.6

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No	Square	Cube.	Square Root.	Cube Root.	Log.	1000 × Recip.	No. = Diameter.	
							Circum.	Area.
200	40000	8000000	14.1421	5.8480	2.30103	5.00000	628.32	31415.9
201	40401	8120601	14.1774	5.8578	2.30320	4.97512	631.46	31730.9
202	40804	8242408	14.2127	5.8675	2.30535	4.95050	634.60	32047.4
203	41209	8365427	14.2478	5.8771	2.30750	4.92611	637.74	32365.5
204	41616	8489664	14.2829	5.8868	2.30963	4.90196	640.89	32685.1
205	42025	8615125	14.3178	5.8964	2.31175	4.87805	644.03	33006.4
206	42436	8741816	14.3527	5.9059	2.31387	4.85437	647.17	33329.2
207	42849	8869743	14.3875	5.9155	2.31597	4.83092	650.31	33653.5
208	43264	8998912	14.4222	5.9250	2.31806	4.80769	653.45	33979.5
209	43681	9129329	14.4568	5.9345	2.32015	4.78469	656.59	34307.0
210	44100	9261000	14.4914	5.9439	2.32222	4.76190	659.73	34636.1
211	44521	9393931	14.5258	5.9533	2.32428	4.73934	662.88	34966.7
212	44944	9528128	14.5602	5.9627	2.32634	4.71698	666.02	35298.9
213	45369	9663597	14.5945	5.9721	2.32838	4.69484	669.16	35632.7
214	45796	9800344	14.6287	5.9814	2.33041	4.67290	672.30	35968.1
215	46225	9938375	14.6629	5.9907	2.33244	4.65116	675.44	36305.0
216	46656	10077696	14.6969	6.0000	2.33445	4.62963	678.58	36643.5
217	47089	1 218313	14.7309	6.0092	2.33646	4.60829	681.73	36983.6
218	47524	10360232	14.7648	6.0185	2.33846	4.58716	684.87	37325.3
219	47961	10503459	14.7986	6.0277	2.34044	4.56621	688.01	37668.5
220	48400	10648000	14.8324	6.0368	2.34242	4.54545	691.15	38013.3
221	48841	10793861	14.8661	6.0459	2.34439	4.52489	694.29	38359.6
222	49284	10941048	14.8997	6.0550	2.34635	4.50450	697.43	38707.6
223	49729	11089567	14.9332	6.0641	2.34830	4.48431	700.58	39057.1
224	50176	11239424	14.9666	6.0732	2.35025	4.46429	703.72	39408.1
225	50625	11390625	15.0000	6.0822	2.35218	4.44444	706.86	39760.8
226	51076	11543176	15.0333	6.0912	2.35411	4.42478	710.00	40115.0
227	51529	11697083	15.0665	6.1002	2.35603	4.40529	713.14	40470.8
228	51984	11852352	15.0997	6.1091	2.35793	4.38596	716.28	40828.1
229	52441	12008989	15.1327	6.1180	2.35984	4.36681	719.42	41187.1
230	52900	12167000	15.1658	6.1269	2.36173	4.34783	722.57	41547.6
231	53361	12326391	15.1987	6.1358	2.36361	4.32900	725.71	41909.6
232	53824	12487168	15.2315	6.1446	2.36549	4.31034	728.85	42273.3
233	54289	12649337	15.2643	6.1534	2.36736	4.29185	731.99	42638.5
234	54756	12812904	15.2971	6.1622	2.36922	4.27350	735.13	43005.3
235	55225	12977875	15.3297	6.1710	2.37107	4.25532	738.27	43373.6
236	55696	13144256	15.3623	6.1797	2.37291	4.23729	741.42	43743.5
237	56169	13312053	15.3948	6.1885	2.37475	4.21941	744.56	44115.0
238	56644	13481272	15.4272	6.1972	2.37658	4.20168	747.70	44488.1
239	57121	13651919	15.4596	6.2058	2.37840	4.18410	750.84	44862.7
240	57600	13824000	15.4919	6.2145	2.38021	4.16667	753.98	45238.9
241	58081	13997521	15.5242	6.2231	2.38202	4.14938	757.12	45616.7
242	58564	14172488	15.5563	6.2317	2.38382	4.13223	760.27	45996.1
243	59049	14348907	15.5885	6.2403	2.38561	4.11523	763.41	46377.0
244	59536	14526784	15.6205	6.2488	2.38739	4.09836	766.55	46759.5
245	60025	14706125	15.6525	6.2573	2.38917	4.08163	769.69	47143.5
246	60516	14886936	15.6844	6.2658	2.39094	4.06504	772.83	47529.2
247	61009	15069223	15.7162	6.2743	2.39270	4.04858	775.97	47916.4
248	61504	15252992	15.7480	6.2828	2.39445	4.03226	779.12	48305.1
249	62001	15438249	15.7797	6.2912	2.39620	4.01606	782.26	48695.5

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
250	62500	15625000	15.8114	6.2996	2.39794	4.00000	785.40	49087.4
251	63001	15813251	15.8430	6.3080	2.39967	3.98406	788.54	49480.9
252	63504	16003008	15.8745	6.3164	2.40140	3.96825	791.68	49875.9
253	64009	16194277	15.9060	6.3247	2.40312	3.95257	794.82	50272.6
254	64516	16387064	15.9374	6.3330	2.40483	3.93701	797.96	50670.7
255	65025	16581375	15.9687	6.3413	2.40654	3.92157	801.11	51070.5
256	65536	16777216	16.0000	6.3496	2.40824	3.90625	804.25	51471.9
257	66049	16974593	16.0312	6.3579	2.40993	3.89105	807.39	51874.8
258	66564	17173512	16.0624	6.3661	2.41162	3.87597	810.53	52279.2
259	67081	17373979	16.0935	6.3743	2.41330	3.86100	813.67	52685.3
260	67600	17576000	16.1245	6.3825	2.41497	3.84615	816.81	53092.9
261	68121	17779581	16.1555	6.3907	2.41664	3.83142	819.96	53502.1
262	68644	17984728	16.1864	6.3988	2.41830	3.81679	823.10	53912.9
263	69169	18191447	16.2173	6.4070	2.41996	3.80228	826.24	54325.2
264	69696	18399744	16.2481	6.4151	2.42160	3.78788	829.38	54739.1
265	70225	18609625	16.2788	6.4232	2.42325	3.77358	832.52	55154.6
266	70756	18821096	16.3095	6.4312	2.42488	3.75940	835.66	55571.6
267	71289	19034163	16.3401	6.4393	2.42651	3.74532	838.81	55990.3
268	71824	19248832	16.3707	6.4473	2.42813	3.73134	841.95	56410.4
269	72361	19465109	16.4012	6.4553	2.42975	3.71747	845.09	56832.2
270	72900	19683000	16.4317	6.4633	2.43136	3.70370	848.23	57255.5
271	73441	19902511	16.4621	6.4713	2.43297	3.69004	851.37	57680.4
272	73984	20123648	16.4924	6.4792	2.43457	3.67647	854.51	58106.9
273	74529	20346417	16.5227	6.4872	2.43616	3.66300	857.66	58534.9
274	75076	20570824	16.5529	6.4951	2.43775	3.64964	860.80	58964.6
275	75625	20796875	16.5831	6.5030	2.43933	3.63636	863.94	59395.7
276	76176	21024576	16.6132	6.5108	2.44091	3.62319	867.08	59828.5
277	76729	21253933	16.6433	6.5187	2.44248	3.61011	870.22	60262.8
278	77284	21484952	16.6733	6.5265	2.44404	3.59712	873.36	60698.7
279	77841	21717639	16.7033	6.5343	2.44560	3.58423	876.50	61136.2
280	78400	21952000	16.7332	6.5421	2.44716	3.57143	879.65	61575.2
281	78961	22188041	16.7631	6.5499	2.44871	3.55872	882.79	62015.8
282	79524	22425768	16.7929	6.5577	2.45025	3.54610	885.93	62458.0
283	80089	22665187	16.8226	6.5654	2.45179	3.53357	889.07	62901.8
284	80656	22906304	16.8523	6.5731	2.45332	3.52113	892.21	63347.1
285	81225	23149125	16.8819	6.5808	2.45484	3.50877	895.35	63794.0
286	81796	23393656	16.9115	6.5885	2.45637	3.49650	898.50	64242.4
287	82369	23639903	16.9411	6.5962	2.45788	3.48432	901.64	64692.5
288	82944	23887872	16.9706	6.6039	2.45939	3.47222	904.78	65144.1
289	83521	24137569	17.0000	6.6115	2.46090	3.46021	907.92	65597.2
290	84100	24389000	17.0294	6.6191	2.46240	3.44828	911.06	66052.0
291	84681	24642171	17.0587	6.6267	2.46389	3.43643	914.20	66508.3
292	85264	24897088	17.0880	6.6343	2.46538	3.42466	917.35	66966.2
293	85849	25153757	17.1172	6.6419	2.46687	3.41297	920.49	67425.6
294	86436	25412184	17.1464	6.6494	2.46835	3.40136	923.63	67886.7
295	87025	25672375	17.1756	6.6569	2.46982	3.38983	926.77	68349.3
296	87616	25934336	17.2047	6.6644	2.47129	3.37838	929.91	68813.5
297	88209	26198073	17.2337	6.6719	2.47276	3.36700	933.05	69279.2
298	88804	26463592	17.2627	6.6794	2.47422	3.35570	936.19	69746.5
299	89401	26730899	17.2916	6.6869	2.47567	3.34448	939.34	70215.4

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
300	90000	27000000	17.3205	6.6943	2.47712	3.33333	942.48	70685.8
301	90601	27270901	17.3494	6.7018	2.47857	3.32226	945.62	71157.9
302	91204	27543608	17.3781	6.7092	2.48001	3.31126	948.76	71631.5
303	91809	27818127	17.4069	6.7166	2.48144	3.30033	951.90	72106.6
304	92416	28094464	17.4356	6.7240	2.48287	3.28947	955.04	72583.4
305	93025	28372625	17.4642	6.7313	2.48430	3.27869	958.19	73061.7
306	93636	28652616	17.4929	6.7387	2.48572	3.26797	961.33	73541.5
307	94249	28934443	17.5214	6.7460	2.48714	3.25733	964.47	74023.0
308	94864	29218112	17.5499	6.7533	2.48855	3.24675	967.61	74506.0
309	95481	29503629	17.5784	6.7606	2.48996	3.23625	970.75	74990.6
310	96100	29791000	17.6068	6.7679	2.49136	3.22581	973.89	75476.8
311	96721	30080231	17.6352	6.7752	2.49276	3.21543	977.04	75964.5
312	97344	30371328	17.6635	6.7824	2.49415	3.20513	980.18	76453.8
313	97969	30664297	17.6918	6.7897	2.49554	3.19489	983.32	76944.7
314	98596	30959144	17.7200	6.7969	2.49693	3.18471	986.46	77437.1
315	99225	31255875	17.7482	6.8041	2.49831	3.17460	989.60	77931.1
316	99856	31554496	17.7764	6.8113	2.49969	3.16456	992.74	78426.7
317	100489	31855013	17.8045	6.8185	2.50106	3.15457	995.88	78923.9
318	101124	32157432	17.8326	6.8256	2.50243	3.14465	999.03	79422.6
319	101761	32461759	17.8606	6.8328	2.50379	3.13480	1002.2	79922.9
320	102400	32768000	17.8885	6.8399	2.50515	3.12500	1005.3	80424.8
321	103041	33076161	17.9165	6.8470	2.50651	3.11527	1008.5	80928.2
322	103684	33386248	17.9444	6.8541	2.50786	3.10559	1011.6	81433.2
323	104329	33698267	17.9722	6.8612	2.50920	3.09598	1014.7	81939.8
324	104976	34012224	18.0000	6.8683	2.51055	3.08642	1017.9	82448.0
325	105625	34328125	18.0278	6.8753	2.51188	3.07692	1021.0	82957.7
326	106276	34645976	18.0555	6.8824	2.51322	3.06749	1024.2	83469.0
327	106929	34965783	18.0831	6.8894	2.51455	3.05810	1027.3	83981.8
328	107584	35287552	18.1108	6.8964	2.51587	3.04878	1030.4	84496.3
329	108241	35611289	18.1384	6.9034	2.51720	3.03951	1033.6	85012.3
330	108900	35937000	18.1659	6.9104	2.51851	3.03030	1036.7	85529.9
331	109561	36264691	18.1934	6.9174	2.51983	3.02115	1039.9	86049.0
332	110224	36594368	18.2209	6.9244	2.52114	3.01205	1043.0	86569.7
333	110889	36926037	18.2483	6.9313	2.52244	3.00300	1046.2	87092.0
334	111556	37259704	18.2757	6.9382	2.52375	2.99401	1049.3	87615.9
335	112225	37595375	18.3030	6.9451	2.52504	2.98507	1052.4	88141.3
336	112896	37933056	18.3303	6.9521	2.52634	2.97619	1055.6	88668.3
337	113569	38272753	18.3576	6.9589	2.52763	2.96736	1058.7	89196.9
338	114244	38614472	18.3848	6.9658	2.52892	2.95858	1061.9	89727.0
339	114921	38958219	18.4120	6.9727	2.53020	2.94985	1065.0	90258.7
340	115600	39304000	18.4391	6.9795	2.53148	2.94118	1068.1	90792.0
341	116281	39651821	18.4662	6.9864	2.53275	2.93255	1071.3	91326.9
342	116964	40001688	18.4932	6.9932	2.53403	2.92398	1074.4	91863.3
343	117649	40353607	18.5203	7.0000	2.53529	2.91545	1077.6	92401.3
344	118336	40707584	18.5472	7.0068	2.53656	2.90698	1080.7	92940.9
345	119025	41063625	18.5742	7.0136	2.53782	2.89855	1083.8	93482.0
346	119716	41421736	18.6011	7.0203	2.53908	2.89017	1087.0	94024.7
347	120409	41781923	18.6279	7.0271	2.54033	2.88184	1090.1	94569.0
348	121104	42144192	18.6548	7.0338	2.54158	2.87356	1093.3	95114.9
349	121801	42508549	18.6815	7.0406	2.54283	2.86533	1096.4	95662.3

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
350	122500	42875000	18.7083	7.0473	2.54407	2.85714	1099.6	96211.3
351	123201	43243551	18.7350	7.0540	2.54531	2.84900	1102.7	96761.8
352	123904	43614208	18.7617	7.0607	2.54654	2.84091	1105.8	97314.0
353	124609	43986977	18.7883	7.0674	2.54777	2.83286	1109.0	97867.7
354	125316	44361864	18.8149	7.0740	2.54900	2.82486	1112.1	98423.0
355	126025	44738875	18.8414	7.0807	2.55023	2.81690	1115.3	98979.8
356	126736	45118016	18.8680	7.0873	2.55145	2.80899	1118.4	99538.2
357	127449	45499293	18.8944	7.0940	2.55267	2.80112	1121.5	100098
358	128164	45882712	18.9209	7.1006	2.55388	2.79330	1124.7	100660
359	128881	46268279	18.9473	7.1072	2.55509	2.78552	1127.8	101223
360	129600	46656000	18.9737	7.1138	2.55630	2.77778	1131.0	101788
361	130321	47045881	19.0000	7.1204	2.55751	2.77008	1134.1	102354
362	131044	47437928	19.0263	7.1269	2.55871	2.76243	1137.3	102922
363	131769	47832147	19.0526	7.1335	2.55991	2.75482	1140.4	103491
364	132496	48228544	19.0788	7.1400	2.56110	2.74725	1143.5	104062
365	133225	48627125	19.1050	7.1466	2.56229	2.73973	1146.7	104635
366	133956	49027896	19.1311	7.1531	2.56348	2.73224	1149.8	105209
367	134689	49430863	19.1572	7.1596	2.56467	2.72480	1153.0	105785
368	135424	49836032	19.1833	7.1661	2.56585	2.71739	1156.1	106362
369	136161	50243409	19.2094	7.1726	2.56703	2.71003	1159.2	106941
370	136900	50653000	19.2354	7.1791	2.56820	2.70270	1162.4	107521
371	137641	51064811	19.2614	7.1855	2.56937	2.69542	1165.5	108103
372	138384	51478848	19.2873	7.1920	2.57054	2.68817	1168.7	108687
373	139129	51895117	19.3132	7.1984	2.57171	2.68097	1171.8	109272
374	139876	52313624	19.3391	7.2048	2.57287	2.67380	1175.0	109858
375	140625	52734375	19.3649	7.2112	2.57403	2.66667	1178.1	110447
376	141376	53157376	19.3907	7.2177	2.57519	2.65957	1181.2	111036
377	142129	53582633	19.4165	7.2240	2.57634	2.65252	1184.4	111628
378	142884	54010152	19.4422	7.2304	2.57749	2.64550	1187.5	112221
379	143641	54439939	19.4679	7.2368	2.57864	2.63852	1190.7	112815
380	144400	54872000	19.4936	7.2432	2.57978	2.63158	1193.8	113411
381	145161	55306341	19.5192	7.2495	2.58093	2.62467	1196.9	114009
382	145924	55742968	19.5448	7.2558	2.58206	2.61780	1200.1	114608
383	146689	56181887	19.5704	7.2622	2.58320	2.61097	1203.2	115209
384	147456	56623104	19.5959	7.2685	2.58433	2.60417	1206.4	115812
385	148225	57066625	19.6214	7.2748	2.58546	2.59740	1209.5	116416
386	148996	57512456	19.6469	7.2811	2.58659	2.59067	1212.7	117021
387	149769	57960603	19.6723	7.2874	2.58771	2.58398	1215.8	117628
388	150544	58411072	19.6977	7.2936	2.58883	2.57732	1218.9	118237
389	151321	58863869	19.7231	7.2999	2.58995	2.57069	1221.1	118847
390	152100	59319000	19.7484	7.3061	2.59106	2.56410	1225.2	119459
391	152881	59776471	19.7737	7.3124	2.59218	2.55755	1228.4	120072
392	153664	60236288	19.7990	7.3186	2.59329	2.55102	1231.5	120687
393	154449	60698457	19.8242	7.3248	2.59439	2.54453	1234.6	121304
394	155236	61162984	19.8494	7.3310	2.59550	2.53807	1237.8	121922
395	156025	61629875	19.8746	7.3372	2.59660	2.53165	1240.9	122542
396	156816	62099136	19.8997	7.3434	2.59770	2.52525	1244.1	123163
397	157609	62570773	19.9249	7.3496	2.59879	2.51889	1247.2	123786
398	158404	63044792	19.9499	7.3558	2.59988	2.51256	1250.4	124410
399	159201	63521199	19.9750	7.3619	2.60097	2.50627	1253.5	125036

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
400	160000	64000000	20.0000	7.3681	2.60206	2.50000	1256 6	125664
401	160801	64481201	20.0250	7.3742	2.60314	2.49377	1259.8	126293
402	161604	64964808	20.0499	7.3803	2.60423	2.48756	1262.9	126923
403	162409	65450827	20.0749	7.3864	2.60531	2.48139	1266.1	127556
404	163216	65939264	20.0998	7.3925	2.60638	2.47525	1269.2	128190
405	164025	66430125	20.1246	7.3986	2.60746	2.46914	1272.3	128825
406	164836	66923416	20.1494	7.4047	2.60853	2.46305	1275.5	129462
407	165649	67419143	20.1742	7.4108	2.60959	2.45700	1278.6	130100
408	166464	67917312	20.1990	7.4169	2.61066	2.45098	1281.8	130741
409	167281	68417929	20.2237	7.4229	2.61172	2.44499	1284.9	131382
410	168100	68921009	20.2485	7.4290	2.61278	2.43902	1288.1	132025
411	168921	69426531	20.2731	7.4350	2.61384	2.43309	1291.2	132670
412	169744	69934528	20.2978	7.4410	2.61490	2.42718	1294.3	133317
413	170569	70444997	20.3224	7.4470	2.61595	2.42131	1297.5	133965
414	171396	70957944	20 3470	7.4530	2.61700	2.41546	1300.6	134614
415	172225	71473375	20.3715	7.4590	2.61805	2.40964	1303.8	135265
416	173056	71991296	20.3961	7.4650	2.61909	2.40385	1306.9	135918
417	173889	72' 11713	20.4206	7.4710	2.62014	2.39808	1310.0	136572
418	174724	73034632	20.4450	7.4770	2.62118	2.39234	1313.2	137228
419	175561	73560059	20.4695	7.4829	2.62221	2.38664	1316.3	137885
420	176400	74088000	20.4939	7.4889	2.62325	2.38095	1319.5	138544
421	177241	74618461	20.5183	7.4948	2.62428	2.37530	1322.6	139205
422	178084	75151448	20.5426	7.5007	2.62531	2.36967	1325.8	139867
423	178929	75686967	20.5670	7.5067	2.62634	2.36407	1328.9	140531
424	179776	76225024	20.5913	7 5126	2.62737	2.35849	1332.0	141196
425	180625	76765625	20.6155	7.5185	2.62839	2.35294	1335.2	141863
426	181476	77308776	20.6398	7.5244	2.62941	2.34742	1338.3	142531
427	182329	77854483	20 6640	7.5302	2.63043	2.34192	1341.5	143201
428	183184	78402752	20.6882	7.5361	2.63144	2.33645	1344.6	143872
429	184041	78953589	20.7123	7.5420	2.63246	2.33100	1347.7	144545
430	184900	79507000	20.7364	7.5478	2.63347	2.32558	1350.9	145220
431	185761	80062991	20.7605	7.5537	2.63448	2.32019	1354.0	145896
432	186624	80621568	20.7846	7.5595	2.63548	2.31482	1357.2	146574
433	187489	81182737	20.8087	7.5654	2.63649	2.30947	1360.3	147254
434	188356	81746504	20.8327	7.5712	2.63749	2.30415	1363.5	147934
435	189225	82312875	20.8567	7.5770	2.63849	2.29885	1366.6	148617
436	190096	82881856	20.8806	7.5828	2.63949	2.29358	1369.7	149301
437	190969	83453453	20.9045	7.5886	2.64048	2.28833	1372.9	149987
438	191844	84027672	20.9284	7.5944	2.64147	2.28311	1376.0	150674
439	192721	84604519	20.9523	7.6001	2.64246	2.27790	1379.2	151363
440	193600	85184000	20.9762	7.6059	2.64345	2.27273	1382.3	152053
441	194481	85766121	21.0000	7.6117	2.64444	2.26757	1385.4	152745
442	195364	86350888	21.0238	7.6174	2.64542	2.26244	1388.6	153439
443	196249	86938307	21.0476	7.6232	2.64640	2.25734	1391.7	154134
434	197136	87528384	21.0713	7.6289	2.64738	2.25225	1394.9	154830
445	198025	88121125	21.0950	7.6346	2.64836	2.24719	1398.0	155528
446	198916	88716536	21.1187	7.6403	2.64933	2.24215	1401.2	156228
447	199809	89314623	21.1424	7.6460	2.65031	2.23714	1404.3	156930
448	200704	89915392	21.1660	7.6517	2.65128	2.23214	1407.4	157633
449	201601	90518849	21.1896	7.6574	2.65225	2.22717	1410.6	158337

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
450	202500	91125000	21.2132	7.6631	2.65321	2.22222	1413.7	159043
451	203401	91733851	21.2368	7.6688	2.65418	2.21730	1416.9	159751
452	204304	92345408	21.2603	7.6744	2.65514	2.21239	1420.0	160460
453	205209	92959677	21.2838	7.6801	2.65610	2.20751	1423.1	161171
454	206116	93576664	21.3073	7.6857	2.65706	2.20264	1426.3	161883
455	207025	94196375	21.3307	7.6914	2.65801	2.19780	1429.4	162597
456	207936	94818816	21.3542	7.6970	2.65896	2.19298	1432.6	163313
457	208849	95443993	21.3776	7.7026	2.65992	2.18818	1435.7	164030
458	209764	96071912	21.4009	7.7082	2.66087	2.18341	1438.9	164748
459	210681	96702579	21.4243	7.7138	2.66181	2.17865	1442.0	165468
460	211600	97336000	21.4476	7.7194	2.66276	2.17391	1445.1	166190
461	212521	97972181	21.4709	7.7250	2.66370	2.16920	1448.3	166914
462	213444	98611128	21.4942	7.7306	2.66464	2.16450	1451.4	167639
463	214369	99252847	21.5174	7.7362	2.66558	2.15983	1454.6	168365
464	215296	99897344	21.5407	7.7418	2.66652	2.15517	1457.7	169093
465	216225	100544625	21.5639	7.7473	2.66745	2.15054	1460.8	169823
466	217156	101194696	21.5870	7.7529	2.66839	2.14592	1464.0	170554
467	218089	101847563	21.6102	7.7584	2.66932	2.14133	1467.1	171287
468	219024	102503232	21.6333	7.7639	2.67025	2.13675	1470.3	172021
469	219961	103161709	21.6564	7.7695	2.67117	2.13220	1473.4	172757
470	220900	103823000	21.6795	7.7750	2.67210	2.12766	1476.5	173494
471	221841	104487111	21.7025	7.7805	2.67302	2.12314	1479.7	174234
472	222784	105154048	21.7256	7.7860	2.67394	2.11864	1482.8	174974
473	223729	105823817	21.7486	7.7915	2.67486	2.11417	1486.0	175716
474	224676	106496424	21.7715	7.7970	2.67578	2.10971	1489.1	176460
475	225625	107171875	21.7945	7.8025	2.67669	2.10526	1492.3	177205
476	226576	107850176	21.8174	7.8079	2.67761	2.10084	1495.4	177952
477	227529	108531333	21.8403	7.8134	2.67852	2.09644	1498.5	178701
478	228484	109215352	21.8632	7.8188	2.67943	2.09205	1501.7	179451
479	229441	109902239	21.8861	7.8243	2.68034	2.08768	1504.8	180203
480	230400	110592000	21.9089	7.8297	2.68124	2.08333	1508.0	180956
481	231361	111284641	21.9317	7.8352	2.68215	2.07900	1511.1	181711
482	232324	111980168	21.9545	7.8406	2.68305	2.07469	1514.3	182467
483	233289	112678587	21.9773	7.8460	2.68395	2.07039	1517.4	183225
484	234256	113379904	22.0000	7.8514	2.68485	2.06612	1520.[illegible]	183984
485	235225	114084125	22.0227	7.8568	2.68574	2.06186	1523.7	184745
486	236196	114791256	22.0454	7.8622	2.68664	2.05761	1526.8	185508
487	237169	115501303	22.0681	7.8676	2.68753	2.05339	1530.0	186272
488	238144	116214272	22.0907	7.8730	2.68842	2.04918	1533.1	187038
490	239121	116930169	22.1133	7.8784	2.68931	2.04499	1536.2	187805
490	240100	117649000	22.1359	7.8837	2.69020	2.04082	1539.4	188574
491	241081	118370771	22.1585	7.8891	2.69108	2.03666	1542.5	189345
492	242064	119095488	22.1811	7.8944	2.69197	2.03252	1545.7	190117
493	243049	119823157	22.2036	7.8998	2.69285	2.02840	1548.8	190890
494	244036	120553784	22.2261	7.9051	2.69373	2.02429	1551.9	191665
495	245025	121287375	22.2486	7.9105	2.69461	2.02020	1555.1	192442
496	246016	122023936	22.2711	7.9158	2.69548	2.01613	1558.2	193221
497	247009	122763473	22.2935	7.9211	2.69636	2.01207	1561.4	194000
498	248004	123505992	22.3159	7.9264	2.69723	2.00803	1564.5	194782
499	249001	124251499	22.3383	7.9317	2.69810	2.00401	1567.7	195565

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
500	250000	125000000	22.3607	7.9370	2.69897	2.00000	1570.8	196350
501	251001	125751501	22.3830	7.9423	2.69984	1.99601	1573.9	197136
502	252004	126506008	22.4054	7.9476	2.70070	1.99203	1577.1	197923
503	253009	127263527	22.4277	7.9528	2.70157	1.98807	1580.2	198713
504	254016	128024064	22.4499	7.9581	2.70243	1.98413	1583.4	199504
505	255025	128787625	22.4722	7.9634	2.70329	1.98020	1586.5	200296
506	256036	129554216	22.4944	7.9686	2.70415	1.97629	1589.7	201090
507	257049	130323843	22.5167	7.9739	2.70501	1.97239	1592.8	201886
508	258064	131096512	22.5389	7.9791	2.70586	1.96850	1595.9	202683
509	259081	131872229	22.5610	7.9843	2.70672	1.96464	1599.1	202482
510	260100	132651000	22.5832	7.9896	2.70757	1.96078	1602.2	204282
511	261121	133432831	22.6053	7.9948	2.70842	1.95695	1605.4	205084
512	262144	134217728	22.6274	8.0000	2.70927	1.95312	1608.5	205887
513	263169	135005697	22.6495	8.0052	2.71012	1.94932	1611.6	206692
514	264196	135796744	22.6716	8.0104	2.71096	1.94553	1614.8	207499
515	265225	136590875	22.6936	8.0156	2.71181	1.94175	1617.9	208307
516	266256	137388096	22.7156	8.0208	2.71265	1.93798	1621.1	209117
517	267289	138188413	22.7376	8.0260	2.71349	1.93424	1624.2	209928
518	268324	138991832	22.7596	8.0311	2.71433	1 93050	1627.3	210741
519	269361	139798359	22.7816	8.0363	2.71517	1.92678	1630.5	211556
520	270400	140608000	22.8035	8.0415	2.71600	1.92308	1633.6	212372
521	271441	141420761	22.8254	8.0466	2.71684	1.91939	1636.8	213189
522	272484	142236648	22.8473	8.0517	2.71767	1.91571	1639.9	214008
523	273529	143055667	22.8692	8.0569	2.71850	1.91205	1643.1	214829
524	274576	143877824	22.8910	8.0620	2.71933	1.90840	1646.2	215651
525	275625	144703125	22.9129	8.0671	2 72016	1.90476	1649.3	216475
526	276676	145531576	22.9347	8.0723	2.72099	1.90114	1652.5	217301
527	277729	146363183	22 9565	8.0774	2.72181	1.89753	1655.6	218128
528	278784	147197952	22.9783	8.0825	2.72263	1.89394	1658.8	218956
529	279841	148035889	23.0000	8.0876	2.72346	1.89036	1661.9	219787
530	280900	148877000	23.0217	8.0927	2.72428	1 88679	1665.0	220618
531	281961	149721291	23.0434	8.0978	2.72509	1.88324	1668.2	221452
532	283024	150568768	23.0651	8.1028	2.72591	1.87970	1671.3	222287
533	284089	151419437	23.0868	8.1079	2.72673	1.87617	1674.5	223123
534	285156	152273304	23.1084	8.1130	2.72754	1.87266	1677.6	223961
535	286225	153130375	23.1301	8.1180	2.72835	1.86916	1680.8	224801
536	287296	153990656	23.1517	8.1231	2.72916	1.86567	1683.9	225642
537	288369	154854153	23.1733	8.1281	2.72997	1.86220	1687.0	226484
538	289444	155720872	23.1948	8.1332	2.73038	1.85874	1690.2	227329
539	290521	156590819	23.2164	8.1382	2.73159	1.85529	1693.3	228175
540	291600	157464000	23.2379	8.1433	2.73239	1.85185	1696.5	229022
541	292681	158340421	23.2594	8.1483	2.73320	1.84843	1699.6	229871
542	293764	159220088	23.2809	8.1533	2.73400	1.84502	1702.7	230722
543	294849	160103007	23.3024	8.1583	2.73480	1.84162	1705.9	231574
544	295936	160989184	23.3238	8.1633	2.73560	1.83824	1709.0	232428
545	297025	161878625	23.3452	8.1683	2.73640	1.83486	1712.2	233283
546	298116	162771336	23.3666	8.1733	2.73719	1.83150	1715.3	234140
547	299209	163667323	23.3880	8.1783	2.73799	1.82815	1718.5	234998
548	300304	164566592	23.4094	8.1833	2.73878	1.82482	1721.6	235858
549	301401	165469149	23.4307	8.1882	2.73957	1.82149	1724.7	236720

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
550	302500	166375000	23.4521	8.1932	2.74036	1.81818	1727.9	237583
551	303601	167284151	23.4734	8.1982	2.74115	1.81488	1731.0	238448
552	304704	168196608	23.4947	8.2031	2.74194	1.81159	1734.2	239314
553	305809	169112377	23.5160	8.2081	2.74273	1.80832	1737.3	240182
554	306916	170031464	23.5372	8.2130	2.74351	1.80505	1740.4	241051
555	308025	170953875	23.5584	8.2180	2.74429	1.80180	1743.6	241922
556	309136	171879616	23.5797	8.2229	2.74507	1.79856	1746.7	242795
557	310249	172808693	23.6008	8.2278	2.74586	1.79533	1749.9	243669
558	311364	173741112	23.6220	8.2327	2.74663	1.79211	1753.0	244545
559	312481	174676879	23.6432	8.2377	2.74741	1.78891	1756.2	245422
560	313600	175616000	23.6643	8.2426	2.74819	1.78571	1759.3	246301
561	314721	176558481	23.6854	8.2475	2.74896	1.78253	1762.4	247181
562	315844	177504328	23.7065	8.2524	2.74974	1.77936	1765.6	248063
563	316969	178453547	23.7276	8.2573	2.75051	1.77620	1768.7	248947
564	318096	179406144	23.7487	8.2621	2.75128	1.77305	1771.9	249832
565	319225	180362125	23.7697	8.2670	2.75205	1.76991	1775.0	250719
566	320356	181321496	23.7908	8.2719	2.75282	1.76678	1778.1	251607
567	321489	182284263	23.8118	8.2768	2.75358	1.76367	1781.3	252497
568	322624	183250432	23.8328	8 2816	2.75435	1.76056	1784.4	253388
569	323761	184220009	23.8537	8.2865	2.75511	1.75747	1787.6	254281
570	324900	185193000	23.8747	8.2913	2.75587	1.75439	1790.7	255176
571	326041	186169411	23.8956	8.2962	2.75664	1.75131	1793.9	256072
572	327184	187149248	23.9165	8.3010	2.75740	1.74825	1797.0	256970
573	328329	188132517	23.9374	8.3059	2.75815	1.74520	1800.1	257869
574	329476	189119224	23.9583	8.3107	2.75891	1.74216	1803.3	258770
575	330625	190109375	23.9792	8.3155	2.75967	1.73913	1806.4	259672
576	331776	191102976	24.0000	8.3203	2.76042	1.73611	1809.6	260576
577	332929	192100033	24.0208	8.3251	2.76118	1.73310	1812.7	261482
578	334084	193100552	24.0416	8.3300	2.76193	1.73010	1815.8	262389
579	335241	194104539	24.0624	8.3348	2.76268	1.72712	1819.0	263298
580	336400	195112000	24.0832	8.3396	2.76343	1.72414	1822.1	264208
581	337561	196122941	24.1039	8.3443	2.76418	1.72117	1825.3	265120
582	338724	197137368	24.1247	8.3491	2.76492	1.71821	1828.4	266033
583	339889	198155287	24.1454	8.3539	2.76567	1.71527	1831.6	266948
584	341056	199176704	24.1661	8.3587	2.76641	1.71233	1834.7	267865
585	342225	200201625	24.1868	8.3634	2.76716	1.70940	1837.8	268783
586	343396	201230056	24.2074	8.3682	2.76790	1.70649	1841.0	269701
587	344569	202262003	24.2281	8.3730	2.76864	1.70358	1844.1	270624
588	345744	203297472	24.2487	8.3777	2.76938	1.70068	1847.3	271547
589	346921	204336469	24.2693	8.3825	2.77012	1.69779	1850.4	272471
590	348100	205379000	24.2899	8.3872	2.77085	1.69492	1853.5	273397
591	349281	206425071	24.3105	8.3919	2.77159	1.69205	1856.7	274325
592	350464	207474688	24.3311	8.3967	2.77232	1.68919	1859.8	275254
593	351649	208527857	24.3516	8.4014	2.77305	1.68634	1863.0	276184
594	352836	209584584	24.3721	8.4061	2.77379	1.68350	1866.1	277117
595	354025	210644875	24.3926	8.4108	2.77452	1.68067	1869.3	278051
596	355216	211708736	24.4131	8.4155	2.77525	1.67785	1872.4	278986
597	356409	212776173	24.4336	8.4202	2.77597	1.67504	1875.5	279923
598	357604	213847192	24.4540	8.4249	2.77670	1.67224	1878.7	280862
599	358801	214921799	24.4745	8.4296	2.77743	1.66945	1881.8	281802

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
600	360000	216000000	24.4949	8.4343	2.77815	1.66667	1885.0	282743
601	361201	217081801	24.5153	8.4390	2.77887	1.66389	1888.1	283687
602	362404	218167208	24.5357	8.4437	2.77960	1.66113	1891.2	284631
603	363609	219256227	24.5561	8.4484	2.78032	1.65837	1894.4	285578
604	364816	220348864	24.5764	8.4530	2.78104	1.65563	1897.5	286526
605	366025	221445125	24.5967	8.4577	2.78176	1.65289	1900.7	287475
606	367236	222545016	24.6171	8.4623	2.78247	1.65017	1903.8	288426
607	368449	223648543	24.6374	8.4670	2.78319	1.64745	1907.0	289379
608	369664	224755712	24.6577	8.4716	2.78390	1.64474	1910.1	290333
609	370881	225866529	24.6779	8.4763	2.78462	1.64204	1913.2	291289
610	372100	226981000	24.6982	8.4809	2.78533	1.63934	1916.4	292247
611	373321	228099131	24.7184	8.4856	2.78604	1.63666	1919.5	293206
612	374544	229220928	24.7386	8.4902	2.78675	1.63399	1922.7	294166
613	375769	230346397	24.7588	8.4948	2.78746	1.63132	1925.8	295128
614	376996	231475544	24.7790	8.4994	2.78817	1.62866	1928.9	296092
615	378225	232608375	24.7992	8.5040	2.78888	1.62602	1932.1	297057
616	379456	233744896	24.8193	8.5086	2.78958	1.62338	1935.2	298024
617	380689	234885113	24.8395	8 5132	2.79029	1.62075	1938.4	298992
618	381924	236029032	24.8596	8.5178	2.79099	1.61812	1941.5	299962
619	383161	237176659	24.8797	8.5224	2.79169	1.61551	1944.7	300934
620	384400	238328000	24.8998	8.5270	2.79239	1.61290	1947.8	301907
621	385641	239483061	24.9199	8.5316	2.79309	1.61031	1950.9	302882
622	386884	240641848	24.9399	8.5362	2.79379	1.60772	1954.1	303858
623	388129	241804367	24.9600	8.5408	2.79449	1.60514	1957.2	304836
624	389376	242970624	24.9800	8.5453	2.79518	1.60256	1960.4	305815
625	390625	244140625	25.0000	8.5499	2.79588	1.60000	1963.5	306796
626	391876	245314376	25.0200	8.5544	2.79657	1.59744	1966.6	307779
627	393129	246491883	25.0400	8.5590	2.79727	1.59490	1969.8	308763
628	394384	247673152	25.0599	8.5635	2.79796	1.59236	1972.9	309748
629	395641	248858189	25.0799	8.5681	2.79865	1.58983	1976.1	310736
630	396900	250047000	25.0998	8.5726	2.79934	1.58730	1979.2	311725
631	398161	251239591	25.1197	8.5772	2.80003	1.58479	1982.4	312715
632	399424	252435968	25.1396	8.5817	2.80072	1.58228	1985.5	313707
633	400689	253636137	25.1595	8.5862	2.80140	1.57978	1988.6	314700
634	401956	254840104	25.1794	8.5907	2.80209	1.57729	1991.8	315696
635	403225	256047875	25.1992	8.5952	2.80277	1.57480	1994.9	316692
636	404496	257259456	25.2190	8.5997	2.80346	1.57233	1998.1	317690
637	405769	258474853	25.2389	8.6043	2.80414	1.56986	2001.2	318690
638	407044	259694072	25.2587	8.6088	2.80482	1.56740	2004.3	319692
639	408321	260917119	25.2784	8.6132	2.80550	1.56495	2007.5	320695
640	409600	262144000	25.2982	8.6177	2.80618	1.56250	2010.6	321699
641	410881	263374721	25.3180	8.6222	2.80686	1.56006	2013.8	322705
642	412164	264609288	25.3377	8.6267	2.80754	1.55763	2016.9	323713
643	413449	265847707	25.3574	8.6312	2.80821	1.55521	2020.0	324722
644	414736	267089984	25.3772	8.6357	2.80889	1.55280	2023.2	325733
645	416025	268336125	25.3969	8.6401	2.80956	1.55039	2026.3	326745
646	417316	269586136	25.4165	8.6446	2.81023	1.54799	2029.5	327759
647	418609	270840023	25.4362	8.6490	2.81090	1.54560	2032.6	328775
648	419904	272097792	25.4558	8.6535	2.81158	1.54321	2035.8	329792
649	421201	273359449	25.4755	8.6579	2.81224	1.54083	2038.9	330810

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000 × Recip.	No. = Diameter. Circum.	Area.
650	422500	274625000	25.4951	8.6624	2.81291	1.53846	2042.0	331831
651	423801	275894451	25.5147	8.6668	2.81358	1.53610	2045.2	332853
652	425104	277167808	25.5343	8.6713	2.81425	1.53374	2048.3	333876
653	426409	278445077	25.5539	8.6757	2.81491	1.53139	2051.5	334901
654	427716	279726264	25.5734	8.6801	2.81558	1.52905	2054.6	335927
655	429025	281011375	25.5930	8.6845	2.81624	1.52672	2057.7	336955
656	430336	282300416	25.6125	8.6890	2.81690	1.52439	2060.9	337985
657	431649	283593393	25.6320	8.6934	2.81757	1.52207	2064.0	339016
658	432964	284890312	25.6515	8.6978	2.81823	1.51976	2067.2	340049
659	434281	286191179	25.6710	8.7022	2.81889	1.51745	2070.3	341084
660	435600	287496000	25.6905	8.7066	2.81954	1.51515	2073.5	342119
661	436921	288804781	25.7099	8.7110	2.82020	1.51286	2076.6	343157
662	438244	290117528	25.7294	8.7154	2.82086	1.51057	2079.7	344196
663	439569	291434247	25.7488	8.7198	2.82151	1.50830	2082.9	345237
664	440896	292754944	25.7682	8.7241	2.82217	1.50602	2086.0	346279
665	442225	294079625	25.7876	8.7285	2.82282	1.50376	2089.2	347323
666	443556	295408296	25.8070	8.7329	2.82347	1.50150	2092.3	348368
667	444889	296740963	25.8263	8.7373	2.82413	1.49925	2095.4	349415
668	446224	298077632	25.8457	8.7416	2.82478	1.49701	2098.6	350464
669	447561	299418309	25.8650	8.7460	2.82543	1.49477	2101.7	351514
670	448900	300763000	25.8844	8.7503	2.82607	1.49254	2104.9	352565
671	450241	302111711	25.9037	8.7547	2.82672	1.49031	2108.0	353618
672	451584	303464448	25.9230	8.7590	2.82737	1.48810	2111.2	354673
673	452929	304821217	25.9422	8.7634	2.82802	1.48588	2114.3	355730
674	454276	306182024	25.9615	8.7677	2.82866	1.48368	2117.4	356788
675	455625	307546875	25.9808	8.7721	2.82930	1.48148	2120.6	357847
676	456976	308915776	26.0000	8.7764	2.82995	1.47929	2123.7	358908
677	458329	310288733	26.0192	8.7807	2.83059	1.47711	2126.9	359971
678	459684	311665752	26.0384	8.7850	2.83123	1.47493	2130.0	361035
679	461041	313046839	26.0576	8.7893	2.83187	1.47275	2133.1	362101
680	462400	314432000	26.0768	8.7937	2.83251	1.47059	2136.3	363168
681	463761	315821241	26.0960	8.7980	2.83315	1.46843	2139.4	364237
682	465124	317214568	26.1151	8.8023	2.83378	1.46628	2142.6	365308
683	466489	318611987	26.1343	8.8066	2.83442	1.46413	2145.7	366380
684	467856	320013504	26.1534	8.8109	2.83506	1.46199	2148.9	367453
685	469225	321419125	26.1725	8.8152	2 83569	1.45985	2152.0	368528
686	470596	322828856	26.1916	8.8194	2.83632	1.45773	2155.1	369605
687	471969	324242703	26.2107	8.8237	2.83696	1.45560	2158.3	370684
688	473344	325660672	26.2298	8.8280	2.83759	1.45349	2161.4	371764
689	474721	327082769	26.2488	8.8323	2.83822	1.45138	2164.6	372845
690	476100	328509000	26.2679	8.8366	2.83885	1.44928	2167.7	373928
691	477481	329939371	26.2869	8.8408	2.83948	1.44718	2170.8	375013
692	478864	331373888	26.3059	8.8451	2.84011	1.44509	2174.0	376099
693	480249	332812557	26.3249	8.8493	2.84073	1.44300	2177.1	377187
694	481636	334255384	26.3439	8.8536	2.84136	1.44092	2180.3	378276
695	483025	335702375	26.3629	8.8578	2.84198	1.43885	2183.4	379367
696	484416	337153536	26.3818	8.8621	2.84261	1.43678	2186.6	380459
697	485809	338608873	26.4008	8.8663	2.84323	1.43472	2189.7	381554
698	487204	340068392	26.4197	8.8706	2.84386	1.43267	2192.8	382649
699	488601	341532099	26.4386	8.8748	2.84448	1.43062	2196.0	383746

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
700	490000	343000000	26.4575	8.8790	2.84510	1.42857	2199.1	384845
701	491401	344472101	26.4764	8.8833	2.84572	1.42653	2202.3	385945
702	492804	345948408	26.4953	8.8875	2.84634	1.42450	2205.4	387047
703	494209	347428927	26.5141	8.8917	2.84696	1.42248	2208.5	388151
704	495616	348913664	26.5330	8.8959	2.84757	1.42046	2211.7	389256
705	497025	350402625	26.5518	8.9001	2.84819	1.41844	2214.8	390363
706	498436	351895816	26.5707	8.9043	2.84880	1.41643	2218.0	391471
707	499849	353393243	26.5895	8.9085	2.84942	1.41443	2221.1	392580
708	501264	354894912	26.6083	8.9127	2.85003	1.41243	2224.3	393692
709	502681	356400829	26.6271	8.9169	2.85065	1.41044	2227.4	394805
710	504100	357911000	26.6458	8.9211	2.85126	1.40845	2230.5	395919
711	505521	359425431	26.6646	8.9253	2.85187	1.40647	2233.7	397035
712	506944	360944128	26.6833	8.9295	2.85248	1.40449	2236.8	398153
713	508369	362467097	26.7021	8.9337	2.85309	1.40253	2240.0	399272
714	509796	363994344	26.7208	8.9378	2.85370	1.40056	2243.1	400393
715	511225	365525875	26.7395	8.9420	2.85431	1.39860	2246.2	401515
716	512656	367061696	26.7582	8.9462	2.85491	1.39665	2249.4	402639
717	514089	368601813	26.7769	8.9503	2.85552	1.39470	2252.5	403765
718	515524	370146232	26.7955	8.9545	2.85612	1.39276	2255.7	404892
719	516961	371694959	26.8142	8.9587	2.85673	1.39082	2258.8	406020
720	518400	373248000	26.8328	8.9628	2.85733	1.38889	2261.9	407150
721	519841	374805361	26.8514	8.9670	2.85794	1.38696	2265.1	408282
722	521284	376367048	26.8701	8.9711	2.85854	1.38504	2268.2	409416
723	522729	377933067	26.8887	8.9752	2.85914	1.38313	2271.4	410550
724	524176	379503424	26.9072	8.9794	2 85974	1.38122	2274.5	411687
725	525625	381078125	26.9258	8.9835	2.86034	1.37931	2277.7	412825
726	527076	382657176	26.9444	8.9876	2.86094	1.37741	2280.8	413965
727	528529	384240583	26.9629	8.9918	2.86153	1.37552	2283.9	415106
728	529984	385828352	26.9815	8.9959	2.86213	1.37363	2287.1	416248
729	531441	387420489	27.0000	9.0000	2.86273	1.37174	2290.2	417393
730	532900	389017000	27.0185	9.0041	2.86332	1.36986	2293.4	418539
731	534361	390617891	27.0370	9.0082	2.86392	1.36799	2296.5	419686
732	535824	392223168	27.0555	9.0123	2.86451	1.36612	2299.7	420835
733	537289	393832837	27.0740	9.0164	2.86510	1.36426	2302.8	421986
734	538756	395446904	27.0924	9.0205	2.86570	1.36240	2305.9	423138
735	540225	397065375	27.1109	9.0246	2.86629	1.36054	2309.1	424293
736	541696	398688256	27.1293	9.0287	2.86688	1.35870	2312.2	425448
737	543169	400315553	27 1477	9.0328	2.86747	1.35685	2315.4	426604
738	544644	401947272	27.1662	9.0369	2.86806	1.35501	2318.5	427762
739	546121	403583419	27.1846	9.0410	2.86864	1.35318	2321.6	428922
740	547600	405224000	27.2029	9.0450	2.86923	1.35135	2324.8	430084
741	549081	406869021	27.2213	9.0491	2.86982	1.34953	2327.9	431247
742	550564	408518488	27.2397	9.0532	2.87040	1.34771	2331.1	432412
743	552049	410172407	27.2580	9.0572	2.87099	1.34590	2334.2	433578
744	553536	411830784	27.2764	9.0613	2.87157	1.34409	2337.3	434746
745	555025	413493625	27.2947	9.0654	2.87216	1.34228	2340.5	435916
746	556516	415160936	27.3130	9.0694	2.87274	1.34048	2343.6	437087
747	558009	416832723	27.3313	9.0735	2.87332	1.33869	2346.8	438259
748	559504	418508992	27.3496	9.0775	2.87390	1.33690	2349.9	439433
749	561001	420189749	27 3679	9.0816	2.87448	1.33511	2353.1	440609

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000 × Recip.	No. = Diameter.	
							Circum.	Area.
750	562500	421875000	27.3861	9.0856	2.87506	1.33333	2356.2	441786
751	564001	423564751	27.4044	9.0896	2 87564	1.33156	2359.3	442965
752	565504	425259008	27.4226	9.0937	2.87622	1.32979	2362.5	444146
753	567009	426957777	27.4408	9.0977	2.87680	1.32802	2365.6	445328
754	568516	428661064	27.4591	9.1017	2.87737	1.32626	2368.8	446511
755	570025	430368875	27.4773	9.1057	2.87795	1.32450	2371.9	447697
756	571536	432081216	27.4955	9.1098	2.87852	1.32275	2375.0	448883
757	573049	433798093	27.5136	9.1138	2.87910	1.32100	2378.2	450072
758	574564	435519512	27.5318	9.1178	2.87967	1.31926	2381.3	451262
759	576081	437245479	27.5500	9.1218	2.88024	1.31752	2384.5	452453
760	577600	438976000	27.5681	9.1258	2.88081	1.31579	2387.6	453646
761	579121	440711081	27.5862	9.1298	2.88138	1.31406	2390.8	454841
762	580644	442450728	27.6043	9.1338	2.88196	1.31234	2393.9	456037
763	582169	444194947	27.6225	9.1378	2.88252	1.31062	2397.0	457234
764	583696	445943744	27.6405	9.1418	2.88309	1.30890	2400.2	458434
765	585225	447697125	27.6586	9.1458	2.88366	1.30719	2403.3	459635
766	586756	449455096	27.6767	9.1498	2.88423	1.30548	2406.5	460837
767	588289	451217663	27.6948	9.1537	2.88480	1.30378	2409.6	462042
768	589824	452984832	27.7128	9.1577	2.88536	1.30208	2412.7	463247
769	591361	454756609	27.7308	9.1617	2.88593	1.30039	2415.9	464454
770	592900	456533000	27.7489	9.1657	2.88649	1.29870	2419.0	465663
771	594441	458314011	27.7669	9.1696	2.88705	1.29702	2422.2	466873
772	595984	460099648	27.7849	9.1736	2.88762	1.29534	2425.3	468085
773	597529	461889917	27.8029	9.1775	2.88818	1.29366	2428.5	469298
774	599076	463684824	27.8209	9.1815	2.88874	1.29199	2431.6	470513
775	600625	465484375	27.8388	9.1855	2.88930	1.29032	2434.7	471730
776	602176	467288576	27.8568	9.1894	2.88986	1.28866	2437.9	472948
777	603729	469097433	27.8747	9.1933	2.89042	1.28700	2441.0	474168
778	605284	470910952	27.8927	9.1973	2.89098	1.28535	2444.2	475389
779	606841	472729139	27.9106	9.2012	2.89154	1.28370	2447.3	476612
780	608400	474552000	27.9285	9.2052	2.89209	1.28205	2450.4	477836
781	609961	476379541	27.9464	9.2091	2.89265	1.28041	2453.6	479062
782	611524	478211768	27.9643	9.2130	2.89321	1.27877	2456.7	480290
783	613089	480048687	27.9821	9.2170	2.89376	1.27714	2459.9	481519
784	614656	481890304	28.0000	9.2209	2.89432	1.27551	2463.0	482750
785	616225	483736625	28.0179	9.2248	2.89487	1.27389	2466.2	483982
786	617796	485587656	28.0357	9.2287	2.89542	1.27226	2469.3	485216
787	619369	487443403	28.0535	9.2326	2.89597	1.27065	2472.4	486451
788	620944	489303872	28.0713	9.2365	2.89653	1.26904	2475.6	487688
789	622521	491169069	28.0891	9.2404	2.89708	1.26743	2478.7	488927
790	624100	493039000	28.1069	9.2443	2.89763	1.26582	2481.9	490167
791	625681	494913671	28.1247	9.2482	2.89818	1.26422	2485.0	491409
792	627264	496793088	28.1425	9.2521	2.89873	1.26263	2488.1	492652
793	628849	498677257	28.1603	9.2560	2.89927	1.26103	2491.3	493897
794	630436	500566184	28.1780	9.2599	2.89982	1.25945	2494.4	495143
795	632025	502459875	28.1957	9.2638	2.90037	1.25786	2497.6	496391
796	633616	504358336	28.2135	9.2677	2.90091	1.25628	2500.7	497641
797	635209	506261573	28.2312	9.2716	2.90146	1.25471	2503.8	498892
798	636804	508169592	28.2489	9.2754	2.90200	1.25313	2507.0	50[illegible]145
799	638401	510082399	28.2666	9.2793	2.90255	1.25156	2510.1	501399

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
800	640000	512000000	28.2843	9.2832	2.90309	1.25000	2513.3	502655
801	641601	513922401	28.3019	9.2870	2.90363	1.24844	2516.4	503912
802	643204	515849608	28.3196	9.2909	2.90417	1.24688	2519.6	505171
803	644809	517781627	28.3373	9.2948	2.90472	1.24533	2522.7	506432
804	646416	519718464	28.3549	9.2986	2.90526	1.24378	2525.8	507694
805	648025	521660125	28.3725	9.3025	2.90580	1.24224	2529.0	508958
806	649636	523606616	28.3901	9.3063	2.90634	1.24069	2532.1	510223
807	651249	525557943	28.4077	9.3102	2.90687	1.23916	2535.3	511490
808	652864	527514112	28.4253	9.3140	2.90741	1.23762	2538.4	512758
809	654481	529475129	28.4429	9.3179	2.90795	1.23609	2541.5	514028
810	656100	531441000	28.4605	9.3217	2.90849	1.23457	2544.7	515300
811	657721	533411731	28.4781	9.3255	2.90902	1.23305	2547.8	516573
812	659344	535387328	28.4956	9.3294	2.90956	1.23153	2551.0	517848
813	660969	537367797	28.5132	9.3332	2.91009	1.23001	2554.1	519124
814	662596	539353144	28.5307	9.3370	2.91062	1.22850	2557.3	520402
815	664225	541343375	28.5482	9.3408	2.91116	1.22699	2560.4	521681
816	665856	543338496	28.5657	9.3447	2.91169	1.22549	2563.5	522962
817	667489	545338513	28.5832	9.3485	2.91222	1.22399	2566.7	524245
818	669124	547343432	28.6007	9.3523	2.91275	1.22249	2569.8	525529
819	670761	549353259	28.6182	9.3561	2.91328	1.22100	2573.0	526814
820	672400	551368000	28.6356	9.3599	2.91381	1.21951	2576.1	528102
821	674041	553387661	28.6531	9.3637	2.91434	1.21803	2579.2	529391
822	675684	555412248	28.6705	9.3675	2.91487	1.21655	2582.4	530681
823	677329	557441767	28.6880	9.3713	2.91540	1.21507	2585.5	531973
824	678976	559476224	28.7054	9.3751	2.91593	1.21359	2588.7	533267
825	680625	561515625	28.7228	9.3789	2.91645	1.21212	2591.8	534562
826	682276	563559976	28.7402	9.3827	2.91698	1.21065	2595.0	535858
827	683929	565609283	28.7576	9.3865	2.91751	1.20919	2598.1	537157
828	685584	567663552	28.7750	9.3902	2.91803	1.20773	2601.2	538456
829	687241	569722789	28.7924	9.3940	2.91855	1.20627	2604.4	539758
830	688900	571787000	28.8097	9.3978	2.91908	1.20482	2607.5	541061
831	690561	573856191	28.8271	9.4016	2.91960	1.20337	2610.7	542365
832	692224	575930368	28.8444	9.4053	2.92012	1.20192	2613.8	543671
833	693889	578009537	28.8617	9.4091	2.92065	1.20048	2616.9	544979
834	695556	580093704	28.8791	9.4129	2.92117	1.19904	2620.1	546288
835	697225	582182875	28.8964	9.4166	2.92169	1.19760	2623.2	547599
836	698896	584277056	28.9137	9.4204	2.92221	1.19617	2626.4	548912
837	700569	586376253	28.9310	9.4241	2.92273	1.19474	2629.5	550226
838	702244	588480472	28.9482	9.4279	2.92324	1.19332	2632.7	551541
839	703921	590589719	28.9655	9.4316	2.92376	1.19189	2635.8	552858
840	705600	592704000	28.9828	9.4354	2.92428	1.19048	2638.9	554177
841	707281	594823321	29.0000	9.4391	2.92480	1.18906	2642.1	555497
842	708964	596947688	29.0172	9.4429	2.92531	1.18765	2645.2	556819
843	710649	599077107	29.0345	9.4466	2.92583	1.18624	2648.4	558142
844	712336	601211584	29.0517	9.4503	2.92634	1.18483	2651.5	559467
845	714025	603351125	29.0689	9.4541	2.92686	1.18343	2654.6	560794
846	715716	605495736	29.0861	9.4578	2.92737	1.18203	2657.8	562122
847	717409	607645423	29.1033	9.4615	2.92788	1.18064	2660.9	563452
848	719104	609800192	29.1204	9.4652	2.92840	1.17925	2664.1	564783
849	720801	611960049	29.1376	9.4690	2.92891	1.17786	2667.2	566116

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000× Recip	No. = Diameter.	
							Circum.	Area.
850	722500	614125000	29.1548	9.4727	2.92942	1.17647	2670.4	567450
851	724201	616295051	29.1719	9.4764	2.92993	1.17509	2673.5	568786
852	725904	618470208	29.1890	9.4801	2.93044	1.17371	2676.6	570124
853	727609	620650477	29.2062	9.4838	2.93095	1.17233	2679.8	571463
854	729316	622835864	29.2233	9.4875	2.93146	1.17096	2682.9	572803
855	731025	625026375	29.2404	9.4912	2.93197	1.16959	2686.1	574146
856	732736	627222016	29.2575	9.4949	2.93247	1.16822	2689.2	575490
857	734449	629422793	29.2746	9.4986	2.93298	1.16686	2692.3	576835
858	736164	631628712	29.2916	9.5023	2.93349	1.16550	2695.5	578182
859	737881	633839779	29.3087	9.5060	2.93399	1.16414	2698.6	579530
860	739600	636056000	29.3258	9.5097	2.93450	1.16279	2701.8	580880
861	741321	638277381	29.3428	9.5134	2.93500	1.16144	2704.9	582232
862	743044	640503928	29.3598	9.5171	2.93551	1.16009	2708.1	583585
863	744769	642735647	29.3769	9.5207	2.93601	1.15875	2711.2	584940
864	746496	644972544	29.3939	9.5244	2.93651	1.15741	2714.3	586297
865	748225	647214625	29.4109	9.5281	2.93702	1.15607	2717.5	587655
866	749956	649461896	29.4279	9.5317	2.93752	1.15473	2720.6	589014
867	751689	651714363	29.4449	9.5354	2.93802	1.15340	2723.8	590375
868	753424	653972032	29.4618	9.5391	2.93852	1.15207	2726.9	591738
869	755161	656234909	29.4788	9.5427	2.93902	1.15075	2730.0	593102
870	756900	658503000	29.4958	9.5464	2.93952	1.14943	2733.2	594468
871	758641	660776311	29.5127	9.5501	2.94002	1.14811	2736.3	595835
872	760384	663054848	29.5296	9.5537	2.94052	1.14679	2739.5	597204
873	762129	665338617	29.5466	9.5574	2.94101	1.14548	2742.6	598575
874	763876	667627624	29.5635	9.5610	2.94151	1.14416	2745.8	599947
875	765625	669921875	29.5804	9.5647	2.94201	1.14286	2748.9	601320
876	767376	672221376	29.5973	9.5683	2.94250	1.14155	2752.0	602696
877	769129	674526133	29.6142	9.5719	2.94300	1.14025	2755.2	604073
878	770884	676836152	29.6311	9.5756	2.94349	1.13895	2758.3	605451
879	772641	679151439	29.6479	9.5792	2.94399	1.13766	2761.5	606831
880	774400	681472000	29.6648	9.5828	2.94448	1.13636	2764.6	608212
881	776161	683797841	29.6816	9.5865	2.94498	1.13507	2767.7	609595
882	777924	686128968	29.6985	9.5901	2.94547	1.13379	2770.9	610980
883	779689	688465387	29.7153	9.5937	2.94596	1.13250	2774.0	612366
884	781456	690807104	29.7321	9.5973	2.94645	1.13122	2777.2	613754
885	783225	693154125	29.7489	9.6010	2.94694	1.12994	2780.3	615143
886	784996	695506456	29.7658	9.6046	2.94743	1.12867	2783.5	616534
887	786769	697864103	29.7825	9.6082	2.94792	1.12740	2786.6	617927
888	788544	700227072	29.7993	9.6118	2.94841	1.12613	2789.7	619321
889	790321	702595369	29.8161	9.6154	2.94890	1.12486	2792.9	620717
890	792100	704969000	29.8329	9.6190	2.94939	1.12360	2796.0	622114
891	793881	707347971	29.8496	9.6226	2.94988	1.12233	2799.2	623513
892	795664	709732288	29.8664	9.6262	2.95036	1.12108	2802.3	624913
893	797449	712121957	29.8831	9.6298	2.95085	1.11982	2805.4	626315
894	799236	714516984	29.8998	9.6334	2.95134	1.11857	2808.6	627718
895	801025	716917375	29.9166	9.6370	2.95182	1.11732	2811.7	629124
896	802816	719323136	29.9333	9.6406	2.95231	1.11607	2814.9	630530
897	804609	721734273	29.9500	9.6442	2.95279	1.11483	2818.0	631938
898	806404	724150792	29.9666	9.6477	2.95328	1.11359	2821.2	633348
899	808201	726572699	29.9833	9.6513	2.95376	1.11235	2824.3	634760

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root.	Log.	1000 × Recip.	No. = Diameter.	
							Circum.	Area.
900	810000	729000000	30.0000	9.6549	2.95424	1.11111	2827.4	636173
901	811801	731432701	30.0167	9.6585	2.95472	1.10988	2830.6	637587
902	813604	733870808	30.0333	9.6620	2.95521	1.10865	2833 7	639003
903	815409	736314327	30.0500	9.6656	2.95569	1.10742	2836.9	640421
904	817216	738763264	30.0666	9.6692	2.95617	1.10619	2840.0	641840
905	819025	741217625	30.0832	9.6727	2.95665	1.10497	2843.1	643261
906	820836	743677416	30.0998	9.6763	2.95713	1.10375	2846.3	644683
907	822649	746142643	30.1164	9.6799	2.95761	1.10254	2849.4	646107
908	824464	748613312	30.1330	9.6834	2.95809	1.10132	2852.6	647533
909	826281	751089429	30.1496	9.6870	2.95856	1.10011	2855.7	648960
910	828100	753571000	30.1662	9.6905	2.95904	1.09890	2858.8	650388
911	829921	756058031	30.1828	9.6941	2.95952	1.09769	2862.0	651818
912	831744	758550528	30.1993	9.6976	2.95999	1.09649	2865.1	653250
913	833569	761048497	30.2159	9.7012	2.96047	1.09529	2668.3	654684
914	835396	763551944	30.2324	9.7047	2.96095	1.09409	2871.4	656118
915	837225	766060875	30.2490	9.7082	2.96142	1.09290	2874.6	657555
916	839056	768575296	30.2655	9.7118	2.96190	1.09170	2877.7	658993
917	840889	771095213	30.2820	9.7153	2.96237	1.09051	2880.8	660433
918	842724	773620632	30.2985	9.7188	2.96284	1.08932	2884.0	661874
919	844561	776151559	30.3150	9.7224	2.96332	1.08814	2887.1	663317
920	846400	778688000	30.3315	9.7259	2.96379	1.08696	2890.3	664761
921	848241	781229961	30.3480	9.7294	2.96426	1.08578	2893.4	666207
922	850084	783777448	30.3645	9.7329	2.96473	1.08460	2896.5	667654
923	851929	786330467	30.3809	9.7364	2.96520	1.08342	2899.7	669103
924	853776	788889024	30.3974	9.7400	2.96567	1.08225	2902.8	670554
925	855625	791453125	30.4138	9.7435	2.96614	1.08108	2906.0	672006
926	857476	794022776	30.4302	9.7470	2.96661	1.07991	2909.1	673460
927	859329	796597983	30.4467	9.7505	2.96708	1.07875	2912.3	674915
928	861184	799178752	30.4631	9 7540	2.96755	1.07759	2915.4	676372
929	863041	801765089	30.4795	9.7575	2.96802	1.07643	2918.5	677831
930	864900	804357000	30.4959	9.7610	2.96848	1.07527	2921.7	679291
931	866761	806954491	30.5123	9.7645	2.96895	1.07411	2924.8	680752
932	868624	809557568	30.5287	9.7680	2.96942	1.07296	2928.0	682216
933	870489	812166237	30.5450	9.7715	2.96988	1.07181	2931.1	683680
934	872356	814780504	30.5614	9.7750	2.97035	1.07066	2934.2	685147
935	874225	817400375	30.5778	9.7785	2.97081	1.06952	2937.4	686615
936	876096	820025856	30.5941	9.7819	2.97128	1.06838	2940.5	688084
937	877969	822656953	30.6105	9.7854	2.97174	1.06724	2943.7	689555
938	879844	825293672	30.6268	9.7889	2.97220	1.06610	2946.8	691028
939	881721	827936019	30.6431	9.7924	2.97267	1.06496	2950.0	692502
940	883600	830584000	30.6594	9.7959	2.97313	1.06383	2953.1	693978
941	885481	833237621	30.6757	9.7993	2.97359	1.06270	2956.2	695455
942	887364	835896888	30.6920	9.8028	2.97405	1.06157	2959.4	696934
943	889249	838561807	30.7083	9.8063	2.97451	1.06045	2962.5	698415
944	891136	841232384	30.7246	9.8097	2.97497	1.05932	2965.7	699897
945	893025	843908625	30.7409	9.8132	2.97543	1.05820	2968.8	701380
946	894916	846590536	30.7571	9.8167	2.97589	1.05708	2971.9	702865
947	896809	849278123	30.7734	9.8201	2.97635	1.05597	2975.1	704352
948	898704	851971392	30.7896	9.8236	2.97681	1.05485	2978.2	705840
949	900601	854670349	30.8058	9.8270	2.97727	1.05374	2941.4	707330

SQUARES, CUBES, SQUARE ROOTS, CUBE ROOTS, LOGARITHMS, RECIPROCALS, CIRCUMFERENCES, AND CIRCULAR AREAS OF NOS. FROM 1 TO 1000—(*Continued*).

No.	Square	Cube.	Square Root.	Cube Root	Log.	1000× Recip.	No. = Diameter.	
							Circum.	Area.
950	902500	857375000	30.8221	9.8305	2.97772	1.05263	2984.5	708822
951	904401	860085351	30.8383	9.8339	2.97818	1.05152	2987.7	710315
952	906304	862801408	30.8545	9.8374	2.97864	1.05042	2990.8	711809
953	908209	865523177	30.8707	9.8408	2.97909	1.04932	2993.9	713306
954	910116	868250664	30.8869	9.8443	2.97955	1.04822	2997.1	714803
955	912025	870983875	30.9031	9.8477	2.98000	1 04712	3000.2	716303
956	913936	873722816	30.9192	9.8511	2.98046	1.04603	3003.4	717804
957	915849	876467493	30.9354	9.8546	2.98091	1.04493	3006.5	719306
958	917764	879217912	30.9516	9.8580	2.98137	1.04384	3009.6	720810
959	919681	881974079	30.9677	9.8614	2.98182	1.04275	3012.8	722316
960	921600	884736000	30.9839	9.8648	2.98227	1.04167	3015.9	723823
961	923521	887503681	31.0000	9.8683	2.98272	1.04058	3019.1	725332
962	925444	890277128	31.0161	9.8717	2.98318	1.03950	3022.2	726842
963	927369	893056347	31.0322	9.8751	2.98363	1.03842	3025.4	728354
964	929296	895841344	31.0483	9.8785	2.98408	1.03734	3028.5	729867
965	931225	898632125	31.0644	9.8819	2 98453	1 03627	3031.6	731382
966	933156	901428696	31.0805	9.8854	2.98498	1.03520	3034.8	732899
967	935089	904231063	31.0966	9.8888	2.98543	1.03413	3037.9	734417
968	937024	907039232	31.1127	9.8922	2.98588	1.03306	3041.1	735937
969	938961	909853209	31.1238	9.8956	2.98632	1.03199	3044.2	737458
970	940900	912673000	31.1448	9.8990	2.98677	1.03093	3047.3	738981
971	942841	915498611	31.1609	9.9024	2.98722	1.02987	3050.5	740506
972	944784	918330048	31.1769	9.9058	2.98767	1.02881	3053.6	742032
973	946729	921167317	31.1929	9.9092	2.98811	1.02775	3056.8	743559
974	948676	924010424	31.2090	9.9126	2.98856	1.02669	3059.9	745088
975	950625	926859375	31.2250	9.9160	2.98900	1.02564	3063.1	746619
976	952576	929714176	31.2410	9.9194	2.98945	1.02459	3066.2	748151
977	954529	932574833	31.2570	9.9227	2.98989	1.02354	3069.3	749685
978	956484	935441352	31.2730	9.9261	2.99034	1.02249	3072.5	751221
979	958441	938313739	31.2890	9.9295	2.99078	1.02145	3075.6	752758
980	960400	941192000	31.3050	9.9329	2.99123	1.02041	3078.8	754296
981	962361	944076141	31.3209	9.9363	2.99167	1.01937	3081.9	755837
982	964324	946966168	31.3369	9.9396	2.99211	1.01833	3085.0	757378
983	966289	949862087	31.3528	9.9430	2.99255	1.01729	3088.2	758922
984	968256	952763904	31.3688	9.9464	2.99300	1.01626	3091.3	760466
985	970225	955671625	31.3847	9.9497	2.99344	1.01523	3094.5	762013
986	972196	958585256	31.4006	9.9531	2.99388	1.01420	3097.6	763561
987	974169	961504803	31.4166	9.9565	2.99432	1 01317	3100.8	765111
988	976144	964430272	31.4325	9.9598	2.99476	1.01215	3103.9	766662
989	978121	967361669	31.4484	9.9632	2.99520	1.01112	3107.0	768214
990	980100	970299000	31.4643	9.9666	2.99564	1.01010	3110.2	769769
991	982081	973242271	31.4802	9.9699	2.99607	1.00908	3113.3	771325
992	984064	976191488	31.4960	9.9733	2.99651	1.00306	3116.5	772882
993	986049	979146657	31.5119	9.9766	2.99695	1.00705	3119.6	774441
994	988036	982107784	31.5278	9.9800	2.99739	1.00604	3122.7	776002
995	990025	985074875	31.5436	9.9833	2.99782	1.00503	3125.9	777564
996	992016	988047936	31.5595	9.9866	2.99826	1.00402	3129.0	779128
997	994009	991026973	31.5753	9.9900	2.99870	1.00301	3132.2	780693
998	996004	994011992	31.5911	9.9933	2 99913	1.00200	3135.3	782260
999	998001	997002999	31.6070	9.9967	2.99957	1.00100	3138.5	783828

DECIMALS OF A FOOT FOR EACH $\frac{1}{64}$ OF AN INCH.

Inch.	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
0	0	.0833	.1667	.2500	.3333	.4167	.5000	.5833	.6667	.7500	.8333	.9167
$\frac{1}{64}$	.0013	.0846	.1680	.2513	.3346	.4180	.5013	.5846	.6680	.7513	.8346	.9180
$\frac{1}{32}$	.0026	.0859	.1693	.2526	.3359	.4193	.5026	.5859	.6693	.7526	.8359	.9193
$\frac{3}{64}$	.0039	.0872	.1706	.2539	.3372	.4206	.5039	.5872	.6706	.7539	.8372	.9206
$\frac{1}{16}$	.0052	.0885	.1719	.2552	.3385	.4219	.5052	.5885	.6719	.7552	.8385	.9219
$\frac{5}{64}$	.0065	.0898	.1732	.2565	.3398	.4232	.5065	.5898	.6732	.7565	.8398	.9232
$\frac{3}{32}$	.0078	.0911	.1745	.2578	.3411	.4245	.5078	.5911	.6745	.7578	.8411	.9245
$\frac{7}{64}$	.0091	.0924	.1758	.2591	.3424	.4258	.5091	.5924	.6758	.7591	.8424	.9258
$\frac{1}{8}$	.0104	.0937	.1771	.2604	.3437	.4271	.5104	.5937	.6771	.7604	.8437	.9271
$\frac{9}{64}$	.0117	.0951	.1784	.2617	.3451	.4284	.5117	.5951	.6784	.7617	.8451	.9284
$\frac{5}{32}$	.0130	.0964	.1797	.2630	.3464	.4297	.5130	.5964	.6797	.7630	.8464	.9297
$\frac{11}{64}$	.0143	.0977	.1810	.2643	.3477	.4310	.5143	.5977	.6810	.7643	.8477	.9310
$\frac{3}{16}$	.0156	.0990	.1823	.2656	.3490	.4323	.5156	.5990	.6823	.7656	.8490	.9323
$\frac{13}{64}$	.0169	.1003	.1836	.2669	.3503	.4336	.5169	.6003	.6836	.7669	.8503	.9336
$\frac{7}{32}$	.0182	.1016	.1849	.2682	.3516	.4349	.5182	.6016	.6849	.7682	.8516	.9349
$\frac{15}{64}$	.0195	.1029	.1862	.2695	.3529	.4362	.5195	.6029	.6862	.7695	.8529	.9362
$\frac{1}{4}$	.0208	.1042	.1875	.2708	.3542	.4375	.5208	.6042	.6875	.7708	.8542	.9375
$\frac{17}{64}$	.0221	.1055	.1888	.2721	.3555	.4388	.5221	.6055	.6888	.7721	.8555	.9388
$\frac{9}{32}$	.0234	.1068	.1901	.2 34	.3568	.4401	.5234	.6068	.6901	.7734	.8568	.9401
$\frac{19}{64}$	.0247	.1081	.1914	.2747	.3581	.4414	.5247	.6081	.6914	.7747	.8581	.9414
$\frac{5}{16}$	.0260	.1094	.1927	.2760	.3594	.4427	.5260	.6094	.6927	.7760	.8594	.9427
$\frac{21}{64}$	.0273	.1107	.1940	.2773	.3607	.4440	.5273	.6107	.6940	.7773	.8607	.9440
$\frac{11}{32}$	.0286	.1120	.1953	.2786	.3620	.4453	.5286	.6120	.6953	.7786	.8620	.9453
$\frac{23}{64}$	.0299	.1133	.1966	.2799	.3633	.4466	.5299	.6133	.6966	.7799	.8633	.9466
$\frac{3}{8}$	.0312	.1146	.1979	.2812	.3646	.4479	.5312	.6146	.6979	.7812	.8646	.9479
$\frac{25}{64}$	.0326	.1159	.1992	.2826	.3659	.4492	.5326	.6159	.6992	.7826	.8659	.9492
$\frac{13}{32}$	.0339	.1172	.2005	.2839	.3672	.4505	.5339	.6172	.7105	.7839	.8672	.9505
$\frac{27}{64}$	.0352	.1185	.2018	.2852	.3685	.4518	.5352	.6185	.7018	.7852	.8685	.9518
$\frac{7}{16}$	.0365	.1198	.2031	.2865	.3698	.4531	.5365	.6198	.7031	.7865	.8698	.9531
$\frac{29}{64}$	.0378	.1211	.2044	.2878	.3711	.4544	.5378	.6211	.7044	.7878	.8711	.9544
$\frac{15}{32}$	.0391	.1224	.2057	.2891	.3724	.4557	.5391	.6224	.7057	.7891	.8724	.9557
$\frac{31}{64}$	.0404	.1237	.2070	.2904	.3737	.4570	.5404	.6237	.7070	.7904	.8737	.9570
$\frac{1}{2}$	.0417	.1250	.2083	.2917	.3750	.4583	.5417	.6250	.7083	.7917	.8750	.9583
$\frac{33}{64}$	.0430	.1263	.2096	.2930	.3763	.4596	.5430	.6263	.7096	.7930	.8763	.9596
$\frac{17}{32}$	.0443	.1276	.2109	.2943	.3776	.4609	.5443	.6276	.7109	.7943	.8776	.9609
$\frac{35}{64}$	.0456	.1289	.2122	.2956	.3789	.4622	.5456	.6289	.7122	.7956	.8789	.9622
$\frac{9}{16}$	.0469	.1302	.2135	.2969	.3802	.4635	.5469	.6302	.7135	.7969	.8802	.9635
$\frac{37}{64}$	.0482	.1315	.2148	.2982	.3815	.4648	.5482	.6315	.7148	.7982	.8815	.9648
$\frac{19}{32}$	.0495	.1328	.2161	.2995	.3828	.4661	.5495	.6328	.7161	.7995	.8828	.9661
$\frac{39}{64}$	.0508	.1341	.2174	.3008	.3841	.4674	.5508	.6341	.7174	.8008	.8841	.9674
$\frac{5}{8}$	.0521	.1354	.2188	.3021	.3854	.4688	.5521	.6354	.7188	.8021	.8854	.9688
$\frac{41}{64}$	.0534	.1367	.2201	.3034	.3867	.4701	.5534	.6367	.7201	.8034	.8867	.9701
$\frac{21}{32}$	.0547	.1380	.2214	.3047	.3880	.4714	.5547	.6380	.7214	.8047	.8880	.9714
$\frac{43}{64}$	.0560	.1393	.2227	.3060	.3893	.4727	.5560	.6393	.7227	.8060	.8893	.9727
$\frac{11}{16}$	.0573	.1406	.2240	.3073	.3906	.4740	.5573	.6406	.7240	.8073	.8906	.9740
$\frac{45}{64}$	.0586	.1419	.2253	.3086	.3919	.4753	.5586	.6419	.7253	.8086	.8919	.9753
$\frac{23}{32}$	.0599	.1432	.2266	.3099	.3932	.4766	.5599	.6432	.7266	.8099	.8932	.9766
$\frac{47}{64}$	.0612	.1445	.2279	.3112	.3945	.4779	.5612	.6445	.7279	.8112	.8945	.9779
$\frac{3}{4}$	.0625	.1458	.2292	.3125	.3958	.4792	.5625	.6458	.7292	.8125	.8958	.9792

DECIMALS OF A FOOT FOR EACH $\frac{1}{64}$ OF AN INCH—(*Continued*).

Inch.	0″	1″	2″	3″	4″	5″	6″	7″	8″	9″	10″	11″
$\frac{49}{64}$	.0638	.1471	.2305	.3138	.3971	.4805	.5638	.6471	.7305	.8138	.8971	.9805
$\frac{25}{32}$	.0651	.1484	.2318	.3151	.3984	.4818	.5651	.6484	.7318	.8151	.8984	.9818
$\frac{51}{64}$	.0664	.1497	.2331	.3164	.3997	.4831	.5664	.6497	.7331	.8164	.8997	.9831
$\frac{13}{16}$	.0677	.1510	.2344	.3177	.4010	.4844	.5677	.6510	.7344	.8177	.9010	.9844
$\frac{53}{64}$	.0690	.1523	.2357	.3190	.4023	.4857	.5690	.6523	.7357	.8190	.9023	.9857
$\frac{27}{32}$	.0703	.1536	.2370	.3203	.4036	.4870	.5703	.6536	.7370	.8203	.9036	.9870
$\frac{55}{64}$	.0716	.1549	.2383	.3216	.4049	.4883	.5716	.6549	.7383	.8216	.9049	.9883
$\frac{7}{8}$	.0729	.1562	.2396	.3229	.4062	.4896	.5729	.6562	.7396	.8229	.9062	.9896
$\frac{57}{64}$	.0742	.1576	.2409	.3242	.4076	.4909	.5742	.6576	.7409	.8242	.9076	.9909
$\frac{29}{32}$	.0755	.1589	.2422	.3255	.4089	.4922	.5755	.6589	.7422	.8255	.9089	.9922
$\frac{59}{64}$	.0768	.1602	.2435	.3268	.4102	.4935	.5768	.6602	.7435	.8268	.9102	.9935
$\frac{15}{16}$	.0781	.1615	.2448	.3281	.4115	.4948	.5781	.6615	.7448	.8281	.9115	.9948
$\frac{61}{64}$	.0794	.1628	.2461	.3294	.4128	.4961	.5794	.6628	.7461	.8294	.9128	.9961
$\frac{31}{32}$	.0807	.1641	.2474	.3307	.4141	.4974	.5807	.6641	.7474	.8307	.9141	.9974
$\frac{63}{64}$	.0820	.1654	.2487	.3320	.4154	.4987	.5820	.6654	.7487	.8320	.9154	.9987
1												1.0000

DECIMALS OF AN INCH FOR EACH $\frac{1}{64}$TH.

$\frac{1}{32}$ds.	$\frac{1}{64}$ths.	Decimal.	Fraction.	$\frac{1}{32}$ds.	$\frac{1}{64}$ths.	Decimal.	Fraction.
	1	.015625			33	.515625	
1	2	.03125		17	34	.53125	
	3	.046875			35	.546875	
2	4	.0625	$\frac{1}{16}$	18	36	.5625	$\frac{9}{16}$
	5	.078125			37	.578125	
3	6	.09375		19	38	.59375	
	7	.109375			39	.609375	
4	8	.125	$\frac{1}{8}$	20	40	.625	$\frac{5}{8}$
	9	.140625			41	.640625	
5	10	.15625		21	42	.65625	
	11	.171875			43	.671875	
6	12	.1875	$\frac{3}{16}$	22	44	.6875	$\frac{11}{16}$
	13	.203125			45	.703125	
7	14	.21875		23	46	.71875	
	15	.234375			47	.734375	
8	16	.25	$\frac{1}{4}$	24	48	.75	$\frac{3}{4}$
	17	.265625			49	.765625	
9	18	.28125		25	50	.78125	
	19	.296875			51	.796875	
10	20	.3125	$\frac{5}{16}$	26	52	.8125	$\frac{13}{16}$
	21	.328125			53	.828125	
11	22	.34375		27	54	.84375	
	23	.359375			55	.859375	
12	24	.375	$\frac{3}{8}$	28	56	.875	$\frac{7}{8}$
	25	.390625			57	.890625	
13	26	.40625		29	58	.90625	
	27	.421875			59	.921875	
14	28	.4375	$\frac{7}{16}$	30	60	.9375	$\frac{15}{16}$
	29	.453125			61	.953125	
15	30	.46875		31	62	.96875	
	31	.484375			63	.984375	
16	32	.5	$\frac{1}{2}$	32	64	1.	1

GEOMETRICAL MENSURATION.

Definitions.—A point is a position without dimensions.

A line has one dimension—length.

A surface has two dimensions—length and breadth.

A solid has three dimensions—length, breadth, and thickness.

A right angle is one whose two sides make an angle of 90° with each other; an acute angle is less than a right angle; an obtuse angle is more than a right angle.

A plane figure is a plane bounded on all sides by lines. If the lines are straight the space which they contain is called a polygon.

Polygons are named according to the number of their sides, as: A triangle is a plane figure of three sides; a quadrilateral is a plane figure of four sides; a pentagon is a plane figure of five sides; a hexagon is a plane figure of six sides; a heptagon is a plane figure of seven sides; an octagon is a plane figure of eight sides; a nonagon is a plane figure of nine sides; a decagon is a plane figure of ten sides; an undecagon is a plane figure of eleven sides; a dodecagon is a plane figure of twelve sides.

A circle is a plane bounded by a curved line all points of which are equally distant from the centre.

A trapezium is a polygon of four sides of which no two sides are parallel.

A trapezoid is a polygon of four sides of which two are parallel.

A parallelogram is a polygon bounded by two pairs of parallel sides.

A rhomboid is a parallelogram whose sides are not equal and its angles not right angles.

A rhombus is a parallelogram whose sides are all equal, but whose angles are not right angles.

A rectangle is a parallelogram whose angles are right angles.

A square is a rectangle whose sides are all equal.

Polygons whose sides are all equal are called regular.

An equilateral triangle has all its sides and angles equal; an isosceles triangle has two of its sides and two of its angles equal; a scalene triangle has all its sides and angles unequal.

A quadrilateral is a plane figure bounded by four straight lines.

A diameter is any line drawn through the centre of a figure and terminated by the opposite boundaries.

Wedge.—Solidity of a wedge = area of base × $\frac{1}{2}$ height Solidity of a frustum of a wedge = $\frac{1}{2}$ height × sum of the areas of the two ends.

Prismoidal Formula.—A prismoid is a solid bounded by six plane surfaces only two of which are parallel.

To find the contents of a prismoid, add together the areas of the two parallel surfaces and four times the area of a section taken midway between and parallel to them, and multiply the sum by one-sixth of the perpendicular distance between the parallel surfaces.

Cycloid and Epicycloid.—The cycloid is the curve described by any point in the circumference of a circle when the circle rolls along a straight line.

An epicycloid is the curve described by point in the circumference of a circle when the circle rolls along the outside of another circle.

A hypocycloid is the path described by any point in the circumference of a circle when the circle rolls along the inside of another circle.

An involute is the curve described by the end of a string when unwinding the string from around a cylinder.

Area of cycloid = area of generating circle × 3.

To Find Areas, etc.—Area of a square, a rectangle, a rhombus, or a rhomboid equals the height multiplied by the breadth.

Area of a triangle equals the base multiplied by one-half the height.

Area of a trapezium equals the diagonal multiplied by half the sum of the two perpendiculars.

Area of trapezoid equals one-half the sum of the two parallel sides multiplied by the distance between them.

Area of an irregular polygon is found by dividing it into triangles and adding together the areas of the triangles.

To find the area of a regular polygon when the length of one side is given: Multiply the square of the side by the multiplier opposite to the name of the polygon in column A of the following table.

To compute the radius of a circumscribing circle when the length of one side is given: Multiply the length of a side of the polygon by the number in column B.

To compute the length of a side of a polygon that is contained in a given circle when the radius of the circle is given: Multiply

Name of Polygon	No. of Sides.	A Area.	B Radius of Circumscribed Circle.	C Length of the Side.	D Radius of Inscribed Circle.	Angle Contained between Two Sides.
Triangle........	3	0.433013	0.5773	1.732	0.2887	60°
Tetragon.......	4	1	0.7071	1.4142	0.5	90°
Pentagon.......	5	1.720477	0.8506	1.1756	0.6882	108°
Hexagon........	6	2.598076	1	1	0.866	120°
Heptagon.......	7	3.633912	1.1524	0.8677	1.0383	128.57°
Octagon........	8	4.828427	1.3066	0.7653	1.2071	135°
Nonagon........	9	6.181824	1.4619	0.684	1.3737	140°
Decagon........	10	7.694209	1.618	0.618	1.5383	144°
Undecagon......	11	9.36564	1.7747	0.5634	1.7028	147.27°
Dodecagon......	12	11.196152	1.9319	0.5176	1.866	150°

the radius of the circle by the number opposite the name of the desired polygon in column C.

To compute the radius of a circle that can be inscribed in a given polygon when the length of a side is given: Multiply the length of a side of the polygon by the number opposite the name of the polygon in column D.

Regular Polyhedrons.—DEFINITION.—A regular body is a solid contained within a certain number of similar and equal plane faces, all of which are equal regular polygons.

The whole number of regular bodies which can possibly be found is five.

1. The tetrahedron, or pyramid.
2. The hexahedron, or cube, which has six square faces.
3. The octahedron, which has eight triangular faces.
4. The dodecahedron, which has twelve pentagonal faces.
5. The icosahedron, which has twenty triangular faces.

To find the volume of a regular polyhedron when the radius of the circumscribing sphere is given: Multiply the cube of the radius of the sphere by the multiplier opposite to the body in column 1 of the following table.

Or when the radius of the inscribed sphere is given: Multiply the cube of the radius of the inscribed sphere by the multiplier opposite the body in column 2 of the following table.

Or when the surface is given: Cube the surface given, extract the square root, and multiply the root by the multiplier opposite the body in column 3 of the following table.

Side is length of linear edge of any side of the figure.

To find radius of circumscribed circle when side is given: Multiply the side by the multiplier opposite the body in column 4 of the following table.

To find the radius of inscribed circle when side is given: Multiply the side by the multiplier opposite the body in column 5 of the following table.

To find the area of surface when side is given: Multiply the side by the multiplier opposite the body in column 6 of the following table.

To find the volume when the side is given: Multiply the side by the multiplier opposite the body in column 7 of the following table.

Number of Sides.	Name.	1 Volume by Radius of Circumscribing Sphere.	2 Volume by Radius of Inscribed Circle.	3 Volume by Surface.	4 Radius of Circumscribed Circle.	5 Radius of Inscribed Circle.	6 Area of Surface.	7 Volume by Given Side.
4	Tetrahedron.	0.5132	12.85641	0.0517	0.6124	0.2041	1.7320	0.1178
6	Hexahedron.	1.5396	8.0000	0.06804	0.866	0.5	6.	1.
8	Octahedron	1.33333	6.9282	0.07311	0.7071	0.4082	3.4641	0.4714
12	Dodecahedron.....	2.78517	5.5503	0.08169	1.4012	1.1135	20.6458	7.6631
20	Icosahedron.	2.53615	5.05406	0.0856	0.951	0.7558	86.602	2.1817

Parabola.—A parabola is one of the conic sections made by cutting the cone parallel to its slant.

A hyperbola is a section of a cone cut by a plane at a greater angle through the base than is made by the side of the cone.

To fina the area of a parabola multiply the base by two-thirds the height.

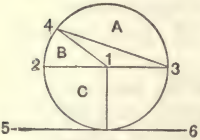


FIG. 341.

Names of the parts of a circle (Fig. 341).

A...........Segment.
B...........Sector.
C...........Quadrant.
1 4..........Radius.
2 3..........Diameter.
4 3..........Chord.
5 6..........Tangent.

The Circle.—A circle is a plane figure bounded by a curve all points of which are equally distant from a point within, called the centre.

The circumference is the curve which bounds the circle.

The radius is a straight line drawn from the centre to the circumference.

The diameter is a straight line drawn through the centre to the circumference on either side.

An arc is any part of the circumference.

A chord is a straight line connecting two points on the circumference.

A segment is that part of the circle contained between the arc and its chord.

A sector is the space included between an arc and two radii drawn to the centre.

A tangent is a straight line which in passing a curve just touches it.

Diameter of a circle $\times 3.1416 =$ the circumference.

Radius of a circle $\times 6.283185 =$ the circumference.

Square of the radius of a circle $\times 3.1416 =$ area.

Square of the diameter of a circle $\times 0.7854 =$ area.

Square of the circumference of a circle $\times 0.07958 =$ area.

Half the circumference of a circle $\times$ by half the diameter $=$ area.

Circumference of a circle $\times 0.159155 =$ radius.

Square root of the area of a circle $\times 0.56419 =$ radius.

Circumference of a circle $\times 0.31831 =$ diameter.

Square root of the area of a circle $\times 1.12838 =$ diameter.

Area of a circle $\div 0.7854$ and square root of the product $=$ the diameter.

Diameter of a circle $\times 0.86 =$ side of inscribed equilateral triangle.

Diameter of a circle $\times 0.7071 =$ side of inscribed square.

Circumference of a circle $\times 0.225 =$ side of an inscribed square.

Circumference of a circle $\times 0.285 =$ side of an equal square.

Diameter of a circle $\times 0.8862 =$ side of an equal square.

Side of a square $\times 1.128397 =$ diameter of circle of equal area.

To find the area of a circular ring formed by two concentric circles: Multiply the sum of the two diameters by their difference and the product by 0.7854. Any circle whose diameter is double that of another contains four times the area of the other.

The areas of all circles are to one another as the squares of their like dimensions. The area of a circle is equal to the area of a triangle whose base equals the circumference and perpendicular equals the radius.

TABLE GIVING AREA OF CIRCLES (IN SQUARE FEET).

D......	0 in.	1 in.	2 in.	3 in.	4 in.	5 in.
Ft.						
1.	.7854	.922	1.07	1.23	1.40	1.58
2.	3.14	3.41	3.69	3.98	4.28	4.59
3.	7.07	7.47	7.88	8.30	8.73	9.17
4.	12.58	13.10	13.64	14.19	14.75	15.32
5.	19.64	20.39	20.97	21.65	22.34	23.04
6.	28.27	29.06	29.87	30.68	31.50	32.34
7.	38.48	39.41	40.34	41.28	42.24	43.20
8.	50.27	51.32	52.37	53.46	54.54	55.64
9.	63.62	64.80	66.00	67.20	68.42	69.64
10.	78.54	79.85	81.18	82.52	83.86	85.22
11.	95.03	96.48	97.93	99.40	100.88	102.37
12.	113.10	114.67	116.26	117.86	119.47	121.09
13.	132.73	134.44	136.16	137.89	139.63	141.38
14.	153.94	155.78	157.63	159.49	161.36	163.24
15.	176.72	178.68	180.66	182.65	184.66	186.67
16.	201.06	203.16	205.27	207.39	209.53	211.67
17.	226.98	229.21	231.45	233.71	235.97	238.24
18.	254.47	256.83	259.20	261.59	263.98	266.39
19.	283.53	286.06	288.52	291.04	293.56	296.11
20.	314.16	316.78	319.42	322.06	324.72	327.39

D......	6 in.	7 in.	8 in.	9 in.	10 in.	11 in.
Ft.						
1.	1.77	1.97	2.18	2.41	2.64	2.89
2.	4.91	5.24	5.59	5.94	6.30	6.68
3.	9.62	10.08	10.56	11.04	11.54	12.05
4.	15.90	16.50	17.10	17.72	18.35	18.99
5.	23.76	24.48	25.22	25.97	26.73	27.49
6.	33.18	34.04	34.91	35.78	36.67	37.57
7.	44.18	45.17	46.16	47.17	48.19	49.22
8.	56.75	57.86	58.99	60.13	61.28	62.44
9.	70.88	72.13	73.39	74.66	75.94	77.24
10.	86.59	87.97	89.36	90.76	92.17	93.60
11.	103.87	105.38	106.90	108.43	109.98	111.53
12.	122.72	124.36	126.01	127.68	129.35	131.04
13.	143.14	144.91	146.69	148.49	150.29	152.11
14.	165.13	167.03	168.95	170.87	172.81	174.76
15	188.69	190.73	192.77	194.83	196.89	198.97
16.	213.83	215.99	218.17	220.35	222.55	224.76
17.	240.53	242.82	245.13	247.45	249.78	252.12
18.	268.80	271.23	273.67	276.12	278.58	281.05
19.	298.64	301.21	303.77	306.36	308.94	311.55
20.	330.06	332.75	335.45	338.16	340.88	343.62

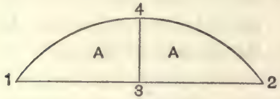


FIG. 342.

1 2 ....Chord.
3 4 ....Rise, versed sine.
1 4 2. ....Arc.
A A.............Segment.

Arc, Segment, etc., of Circles (Fig. 342).—To find the radius of an arc when the chord and rise are given:

Rule.—Square one-half the chord, also square the rise; divide their sum by twice the rise and the answer will be the radius.

To find the rise of an arc when the chord and radius are given:

Rule.—Square the radius; also square one-half the chord; subtract the latter from the former and take the square root of the remainder. Subtract the result from the radius and the remainder will be the rise.

To find the chord of an arc when the chord of half the arc and the rise are given: From the square of the chord of half the arc subtract the square of the versed sine, or rise, and take twice the square root of the remainder.

To find the chord of an arc when the diameter and rise are given: Multiply the rise by 2 and subtract the product from the diameter; then subtract the square of the remainder from the square of the diameter and take the square root of that remainder.

To find the chord of half an arc when the chord of the arc and the rise are given: Take the square root of the sum of the squares of the rise and of half the chord of the arc.

To find the chord of half an arc when the diameter and rise are given: Multiply the diameter by the rise and take the square root of their product.

To find the diameter when the chord of half an arc and the rise are given: Divide the square of the chord of half the arc by the rise.

To find the rise when the chord of half an arc and the diameter are given: Divide the square of the chord of half the arc by the diameter.

To find the rise when the chord of an arc and the diameter are given: From the square of the diameter subtract the square of the chord and extract the square root of the remainder; subtract this root from the diameter and take half the remainder.

To find the length of an are of a circle when the number of degrees and the radius are given: Multiply the radius of the circle by 0.01745 and the product by the degrees in the arc.

To find the length of an arc of a circle when the length is given in degrees, minutes, and seconds: Multiply the number of degrees by 0.01745329 and the product by the radius, and multiply the number of minutes by 0.00029 and that product by the radius, and multiply the number of seconds by 0.00000448 times the radius; add together the three results and the product will be the length of the arc.

To find the area of a sector of a circle when the degrees of the arc and the radius are given: Multiply the number of degrees in the arc by the area of the whole circle and divide by 360.

To find the area of a sector of a circle when the length of the arc is given in degrees and minutes and the radius is given: Reduce the length of the arc to minutes, multiply by the area of the whole circle, and divide by 21,600.

To find the area of a sector of a circle when the length of the arc and the radius are given: Multiply the length of the arc by half the length of the radius and the product is the area.

To find the area of a sector: Multiply one-half of the length of the arc by the radius, or divide the number of degrees in the arc of the sector by 360. Multiply the result by the area of the circle of which the sector is a part.

To find the area of a segment of a circle: Find the area of the sector of which the segment is a part, and from this area subtract the area of the triangle formed by the two radii and the chord of the segment.

Ellipse.—An ellipse is a plane figure bounded by a curved line, to any point of which the sum of the distances from two fixed points within, called the foci, is equal to the sum of the distances from the foci to any other point on the curve.

In Fig. 343, A and B are the foci and C and D any two points on the perimeter. $AC+CB=AD+DB$, and both these sums are equal to the major axis EF. The long diameter EF is called the major axis, and the short diameter GD the minor axis. The foci is located from D or G as a centre, making DA or DB equal to one-half the length of the long diameter.

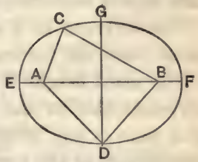


Fig. 343.

There is no exact method of finding the circumference or perimeter of an ellipse, but to approximate close enough for all practical purposes multiply the major axis by 1.82 and the minor axis by 1.315. The sum of the results will be the perimeter.

To find the area of an ellipse: Multiply the product of its two diameters by 0.7854.

When the length of the perimeter and one axis on an ellipse are given, to approximate the length of the other axis, divide the length of the perimeter by 1.6 and from this quotient subtract the length of the given axis.

The Frustum of a Pyramid or Cone.—If a pyramid or cone is cut by a plane parallel to the base, so as to form two parts, the lower part is called the frustum of the pyramid or cone. The upper end of the frustum is called the upper base and the lower end the lower base. The altitude is the perpendicular distance between the bases.

To find the convex area of a frustum of a pyramid or cone, multiply one-half the sum of the circumferences of the bases by the slant height. To find the entire area, add the area of the two bases.

To find the volume of the frustum of a pyramid or cone: Add the areas of the upper base, the lower base, and the square root of the product of the areas of the two bases; multiply this sum by one-third of the length.

Cylinder.—A cylinder is a solid whose ends are equal and similar curved figures.

To find the area of the convex surface of a cylinder: Multiply the circumference of the base by the height; and to find the entire area add the areas of the two ends.

To find the volume or solid contents of a cylinder: Multiply the area of the base by the height.

Pyramid and Cone.—A pyramid is a solid whose base is a polygon, and whose sides are triangles uniting at a common point called the vertex.

A cone is a solid whose base is a circle and whose convex surface tapers uniformly to a point called the vertex.

The altitude of a pyramid or cone is the perpendicular distance from the vertex to the base.

The slant height of a pyramid is a line drawn from the vertex perpendicular to one of the sides of the base The slant height of a cone is any straight line drawn from the vertex to the circumference of the base.

To find the convex area of a pyramid or cone: Multiply the circumference of the base by one-half of the slant height.

To find the volume of a pyramid or cone: Multiply the area of the base by one-third of the altitude.

Sphere.—A sphere is a solid bounded by a uniformly curved surface every point of which is equally distant from a point within called the centre.

The square of the diameter of a sphere $\times 3.1416 =$ its surface.

Circumference of a sphere $\times$ by its diameter $=$ its surface.

Square of the circumference of a sphere × 0.3183 = its surface.

Surface of a sphere × by $\frac{1}{6}$ of its diameter = its solidity.

Cube of the diameter of a sphere × 0.5236 = solidity.

Cube of the radius of a sphere × 4.1888 = solidity.

Cube of the circumference of a sphere × 0.016887 = solidity.

Square root of the surface of a sphere × 0.5236 = solidity.

Square root of the surface of a sphere × 1.772454 = the circumference.

Cube root of the solidity of a sphere × 1.2407 = the diameter.

Cube root of the solidity of a sphere × 3.8978 = the circumference.

Radius of a sphere × 1.1547 = side of inscribed cube.

Square root of ($\frac{1}{3}$ of the square of) the diameter of a sphere = side of inscribed cube.

To find the solidity of a segment of a sphere: To three times the square of the radius of its base add the square of its height; multiply this sum by the height and the product by 0.5236.

SPHERICAL ZONE.—A spherical zone is the part of a sphere included between two parallel planes.

To find the solid contents of a spherical zone: To the sum of the squares of radii of the two ends add one-third of the square of the height of the zone; multiply this sum by the height, and this product by 1.5708.

Miscellaneous Mensuration.—To find the contents of a barrel or cask, multiply the square of the mean diameter by the length (both in inches) and this product by 0.0034; the answer will be the contents in gallons. To find the mean diameter of a barrel or cask, add to the head diameter two-thirds, or, if the staves are but little curved, six-tenths, of the difference between the head and bung diameters.

TO FIND THE CONTENTS OF A ROUND TAPERING STICK OF TIMBER.—Multiply the diameter of one end by the diameter of the other end, and to this product add one-third of the square of the difference of the diameters; then multiply this answer by 0.7854, which gives the mean area between the two ends, which multiplied by the height gives the cubical contents.

TO FIND THE CONTENTS OF TAPERING TIMBER.—Multiply the side of the large end by the side of the small end and to the product add one-third of the square of the difference of the sides, which gives the mean area between the two ends, which multiplied by the length gives the cubical contents.

To Find the Weight of Grindstones.—Multiply the square of the diameter (in inches) by the thickness (in inches), then by the decimal 0.06363; the product will be the weight of the stone in pounds.

Size of Boxes.—A box 4″×4″ square and 4⅛″ deep will hold one quart; a box 7″×4″ square and 4⅘″ deep will hold half a gallon; a box 8″×8″ square and 4⅛″ deep will hold one gallon; a box 8″×8″ square and 8⅖″ deep will hold one peck; a box 16″×8⅖″ square and 8″ deep will hold half a bushel; a box 24″×″16 square and 14″ deep will hold half a barrel; a box 24″×16″ square and 28″ deep will hold one barrel, or three bushels.

To Find the Solid Contents of an Irregular Body.—Immerse it in a vessel partly filled with water; then the contents of that part of the vessel filled by the rising water will be the cubical contents of the body.

Various Formulæ.—To find the horizontal thrust of an arch:

$$\text{Horizontal thrust} = \frac{\text{load on arch} \times \text{span}}{8 \times \text{rise of arch in feet}}.$$

When tension rods are used the diameter of the rod can be found as follows:

$$\text{Diameter of rod in inches} = \frac{\text{total load on arch} \times \text{span}}{8 \times \text{rise of arch in feet } \times 7854}.$$

If two rods are used substitute 16 in place of 8 in the formula, if three rods, 24.

To find the distance from the intrados to the extrados of an arch, in feet:

$$0.2 + \sqrt{\frac{\text{radius} + \text{half span}}{4}}.$$

Strength of stone lintels:
Distributed breaking load

$$= \frac{2 \times \text{breadth in inches} \times \text{square of depth in inches}}{\text{span in feet}} \times C.$$

C for granite, 100; marble, 120; limestone, 83; sandstone, 70; slate, 300; bluestone flagging, 150.

Concentrated load at centre = one-half distributed load.

To find the power of a screw with lever: The power multi-

plied by the circumference which it describes is equal to the weight multiplied by the distance between threads.

To find the power of a lever:

Rule.—As the distance between the weight and the fulcrum is to the distance between the power and the fulcrum, so is the power to the weight.

To find the power of pulleys or set of blocks:

Rule.—As one is to twice the number of movable pulleys, so is the power to the weight.

STRENGTH OF WOODEN BEAMS.—To find the strength of a beam fixed at one end and load at other:

$$\text{Safe load in pounds} = \frac{\text{breadth} \times \text{square of depth} \times A}{4 \times \text{length in feet}}.$$

To find the strength of a beam fixed at one end and load uniformly distributed:

$$\text{Safe load in pounds} = \frac{\text{breadth} \times \text{square of depth} \times A}{2 \times \text{length in feet}}.$$

To find the strength of a beam supported at both ends and loaded at the centre:

$$\text{Safe load in pounds} = \frac{\text{breadth} \times \text{square of depth} \times A}{\text{span in feet}}.$$

To find the strength of a beam supported at both ends and uniformly distributed load:

$$\text{Safe load in pounds} = \frac{2 \times \text{breadth} \times \text{square of depth} \times A}{\text{span in feet}}.$$

To find the strength of a beam supported at both ends and with a concentrated load at any point but the centre:

$$\text{Safe load in pounds} = \frac{\text{breadth} \times \text{square of depth} \times \text{span} \times A}{4 \times B \times C}.$$

To find the strength of a beam supported at both ends and loaded with concentrated loads at two points equally distant from the supports:

$$\text{Safe load in pounds at each point} = \frac{\text{breadth} \times \text{square of depth} \times A}{4 \times C}.$$

In the last two formulæ C = the distance from the weight to the nearest support and B = the distance from the weight to the other support.

The values of the constant A in the above formula are as follows:

Ash	111	White oak	75
Beech	100	White pine	80
Birch	90	Yellow pine	100
Cedar	55	Spruce	90
Hemlock	66		

FLITCH-PLATE GIRDERS.—To find the strength of flitch-plate girders in which the thickness of the iron plate is about $\frac{1}{12}$ of the breadth of the beam (which is about the correct proportion).

Beams supported at both ends:

$$\text{The safe load at centre in pounds} = \frac{D^2}{L}(FB + 750T).$$

$$\text{Safe distributed load in pounds} = \frac{2D^2}{L}(FB + 750T).$$

To find the depth of beam:

$$\text{For distributed load } D = \sqrt{\frac{WL}{2FB + 1500T}}$$

$$\text{For load at centre } D = \sqrt{\frac{WL}{FB + 750T}}$$

In the above formula

D = depth of beam.
B = total thickness of wood.
L = clear span in feet.
T = thickness of iron plate.
$F = \begin{cases} 100 \text{ pounds for hard pine,} \\ 73 \text{ pounds for spruce.} \end{cases}$
W = total load on girder.

HOGCHAINS, OR BELLY-ROD TRUSS.—Stresses in a beam with one strut, Fig. 344, with concentrated load at centre. To

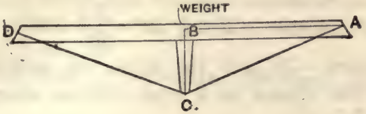


FIG. 344.

find the stress in AC or DC, divide the length of the line AC by the length of the line BC and then multiply this result by one-half the concentrated load.

To find the stress in the beam AD, divide the length of the line AB by the length of the line BC and multiply by one-half the concentrated load.

When the load is distributed over the entire beam, use $\frac{5}{8}$ of the entire load for the load on the strut, or concentrated at centre.

The length of the members in the above rules must be taken in the same unit of measurement. The rules may be expressed by the following formulæ, in which W = weight.

Stress in AC or $DC = \dfrac{AC}{BC} \times \dfrac{W}{2}$ = tensile strength;

Stress in $AD \qquad = \dfrac{AB}{BC} \times \dfrac{W}{2}$ = compression.

Stresses in beams with two struts and load concentrated over the struts, Fig. 345.

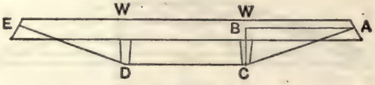


FIG. 345.

To obtain the stress in AC or ED, divide the length of AC by the length of BC and multiply this result by the load at W.

To find the stress in AE or DC, divide the length of the line AB by the length of the line BC and multiply this result by the load at W.

When a beam has two struts placed one-third of its distance from each end, and has a uniformly distributed load, the weight on each strut is $\frac{11}{30}$ of the total load.

The above rules may be expressed in formulæ as follows:

$$\text{Stress in } AC \text{ or } ED = \frac{AH}{BC} \times W;$$

$$\text{Stress in } EA \text{ or } DC = \frac{AB}{BC} \times W.$$

ROOF-TRUSSES.—To find the strain on roof-trusses with a single rod. The strains on a truss built as shown in Fig. 346 are found as follows:

Three-tenths of the distributed weight by half the length of the chord divided by the length of *ab* equals the tensile strain on the chord; five-eighths of weight equals tensile strain on the rod; three-tenths of the distributed weight by the length of the rafter divided by the length of *ab* equals the compression in the rafter. For concentrated weight at the centre: One-half the

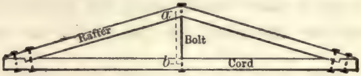


FIG. 346.

weight by half the length of the chord divided by the length of *ab* equals the strain on the chord; the strain on the rod is equal to the weight; one-half the weight by the length of the rafter divided by the length of *ab* equals the compression in the rafter.

TO FIND THE STRAIN ON ROOF-TRUSS WITH TWO RODS.—The strains on a truss built as shown in Fig. 347 are as follows: The distributed weight by 0.367 by one-third the length of the chord,

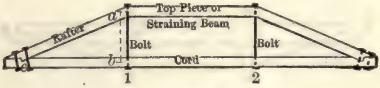


FIG. 347.

or *cb*, divided by the length of *ab*, equals the strain on the chord or the compression of top piece; the weight by 0.367 equals the strain on the rods; the distributed weight by 0.367 by the length of the rafter divided by the length of *ab* equals the compression in the rafter. When the weight is concentrated at 1 and 2: The weight by one-third the length of the chord, or *cb*, divided by the length of *ab*, equals the strain on the chord or the compression of the top piece; the weight equals the strain on the rods; the

weight by the length of the rafter divided by the length of *ab* equals the compression of the rafter.

The diameter of a single rod to carry a given weight may be found by dividing the weight by 9425, and the square root of the product will be the diameter of the rod, allowing 12,000 pounds per square inch in the rod.

When two rods carry a given weight, take half the weight and proceed as above.

TABLES FOR FINDING STRESSES IN MEMBERS FOR ROOF-TRUSSES OF THE DIFFERENT TYPES AND PITCHES AS GIVEN BELOW AND OF ANY SPAN.

Rule.—To find the stress in any member, multiply the coefficient given for that member by total dead load carried by truss (=span in feet × distance between trusses in feet × weight per square foot). If the truss is acted upon by wind forces of other unsymmetrical loading, the stresses in the members must be calculated accordingly and combined with the dead-load stresses as found below.

Member of Truss	Pitch (Depth to Span).			
	$\frac{1}{3}$	30°	$\frac{1}{4}$	$\frac{1}{5}$
Fig. 348.				
Aa	.675	.750	.838	1.010
Bb	.537	.625	.726	.917
Ca	.563	.650	.750	.938
Cc	.375	.433	.500	.625
ab	.208	.217	.224	.232
bc	.188	.217	.250	.313
Fig. 349.				
Aa	.750	.833	.930	1.120
Bb	.589	.666	.757	.928
Cc	.568	.666	.783	.995
Da	.625	.721	.833	1.042
Dd	.375	.433	.500	.625
ab	.155	.167	.180	.202
bc	.155	.167	.180	.202
cd	.250	.288	.333	.417
Fig. 350.				
Aa	.788	.874	.978	1.178
Bb	.718	.812	.922	1.131
Cc	.649	.750	.866	1.085
Dd	.580	.687	.810	1.038
Ea	.655	.758	.875	1.094
Ef	.562	.650	.750	.938
Ee	.375	.433	.500	.625
ab	.104	.108	.112	.116
bf	.093	.108	.125	.156
fg	.208	.216	.224	.232
gc	.093	.108	.125	.156
cd	.104	.108	.112	.116
ge	.187	.217	.250	.313
de	.280	.325	.375	.469

Note.—Heavy lines denote compression and light lines tension members. Loads are considered as concentrated at the joints.

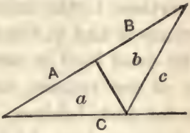


FIG. 348.

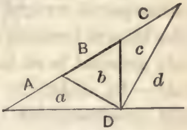


FIG. 349.

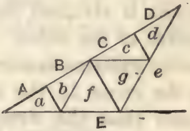


FIG. 350.

Explanation of Tables on Maximum Stresses in Pratt and Whipple Trusses (Pages 628 to 630, inclusive). —These tables give the stress in each member of a Pratt (single quadrangular) or Whipple (double quadrangular) truss, for any number of panels not exceeding twelve in the former and twenty in the latter case, on the assumption that the load is uniform per foot and the panels are all of the same length. The stresses are given in terms of the truss-panel dead and moving loads, represented respectively by W and L. These are obtained by multiplying the dead load per foot of bridge, in the case of W, and the moving or live load per foot of bridge, in the case of L, by half the panel length.

The letters W and L are placed at the top of column in tables, and not next to the figures to which they belong, for want of space.

The stress in aB, for example, in a twelve-panel Pratt truss, $=5.5W+5.5L$, and in $Bc=4.5W+\frac{55}{12}L$, both multiplied by the quotient specified in the last column.

The system of lettering employed is shown by Figs. 351 and 352, on page 627, and, it is believed, is the best in use. By making a sketch of the truss under consideration and lettering the vertices in the manner shown, the truss members to which reference is had in the tables can be readily identified.

The dead load is assumed as concentrated at the lower vertices of the trusses for through bridges and at the upper vertices for deck bridges. For through bridges of very large span, the stresses thus obtained for the posts must be increased by the truss-panel weight of the upper portion of the truss, including the lateral bracing; but in small spans, the increase of stress on this account is so inconsiderable that it is usually neglected.

Note.—In order to calculate the stresses in a Whipple or double quadrangular truss by statical methods, it is necessary to consider the truss as the combination of two Pratt trusses or single systems of bracing and assume that each of these two systems is strained in the same manner as if one were independent of the other. If the number of panels is odd, each of the two systems is unsymmetrical, which has the effect of making the stress in the middle panel of the lower chord slightly smaller than the stress in the corresponding panel of the top chord. The difference is, however, frequently neglected, and the stress in middle panel of bottom chord assumed the same as in middle panel of top chord.

Each of the two systems is assumed to carry one-half of the panel load at the top of the inclined end posts.

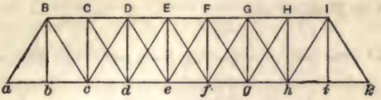


FIG. 351.—Pratt or Single Quadrangular Truss.

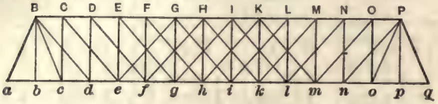


FIG. 352.—Whipple or Double Quadrangular Truss.

Illustration of Application of Tables, also of the Use of Table of Natural Sines, Tangents, and Secants.—A Pratt truss of 135 feet span and 18 feet depth is divided into nine panels of 15 feet each. Required the stress in first main tie *Bc*, and in middle panel *DE* of top chord, for a dead load of 1200 pounds and a moving load of 3000 pounds per lineal foot of bridge.

$$W = \frac{1200}{2} \times 15 = 9000 \text{ pounds;}$$

$$L = \frac{3000}{2} \times 15 = 22{,}500 \quad `` \quad ;$$

$$Bc = \left(3W + \frac{28}{9}L\right) \times \frac{\text{Length } Bc}{18};$$

$$DE = (10W + 10L)\frac{15}{18}.$$

The factor $\frac{15}{18}$, or panel length divided by depth of truss, is the tangent of the angle, for which the length *Bc*, divided by depth of truss, is the secant. By table of natural sines, tangents, and secants, for tangent $= \frac{15}{18} = 0.833$, the secant $= 1.302$; therefore

$$Bc = 97{,}000 \times 1.30 = 126{,}100 \text{ pounds;}$$

$$DE = 315{,}000 \times \frac{15}{18} = 262{,}500$$

MAXIMUM STRESSES UNDER DEAD AND MOVING LOADS IN PRATT OR SINGLE QUADRANGULAR TRUSSES, WITH INCLINED END POSTS AND EQUAL PANELS, FOR THROUGH AND DECK BRIDGES.

W = dead load and *L* = moving load per truss and per panel.

Member.	12-panel Truss.	11-panel Truss.	10-panel Truss.	9-panel Truss.	8-panel Truss.	Multiply by
	$W+L$	$W+L$	$W+L$	$W+L$	$W+L$	
aB	5.5+5.5	5+5	4.5+4.5	4+4	3.5+3.5	Length of member divided by depth of truss.
Bc	4.5+55/12	4+45/11	3.5+3.6	3+28/9	2.5+21/8	
Cd	3.5+45/12	3+36/11	2.5+2.8	2+21/9	1.5+15/8	
De	2.5+36/12	2+28/11	1.5+2.1	1+15/9	0.5+10/8	
Ef	1.5+28/12	1+21/11	0.5+1.5	0+10/9	−0.5+6/8	
Fg	0.5+21/12	0+15/11	−0.5+1.0	−1+6/9	−1.5+3/8	
Gh	−0.5+15/12	−1+10/11	−1.5+0.6	−2+3/9		
Hi	−1.5+10/12	−2+6/11				
abc	5.5+ 5.5	5+ 5	4.5+ 4.5	4+ 4	3.5+3.5	Panel length divided by depth of truss.
BC, *cd*	10.0+10.0	9+ 9	8.0+ 8.0	7+ 7	6.0+6.0	
CD, *de*	13.5+13.5	12+12	10.5+10.5	9+ 9	7.5+7.5	
DE, *ef*	16.0+16.0	14+14	12.0+12.0	10+10	8.0+8.0	
EF, *fg*	17.5+17.5	15+15	12.5+12.5			
FG	18.0+18.0					
Thro. Deck						
Cc	4.5+55/12	4+45/11	3.5+3.6	3+28/9	2.5+21/8	Unity.
Cc, *Dd*	3.5+45/12	3+36/11	2.5+2.8	2+21/9	1.5+15/8	
Dd, *Ee*	2.5+36/12	2+28/11	1.5+2.1	1+15/9	0.5+10/8	
Ee, *Ff*	1.5+28/12	1+21/11	0.5+1.5	0+10/9	−0.5+6/8	
Ff, *Gg*	0.5+21/12	0+15/11	−0.5+1.0			
Gg	−0.5+15/12					

Member.	7-panel Truss.	6-panel Truss.	5-panel Truss.	4-panel Truss.	3-panel Truss.	Multiply by
	$W+L$	$W+L$	$W+L$	$W+L$	$W+L$	
aB	3+3	2.5+2.5	2+2.0	1.5+1.5	1+1	Length of member divided by depth of truss.
Bc	2+15/7	1.5+10/6	1+1.2	0.5+3/4	0+1/3	
Cd	1+10/7	0.5+1.0	0+0.6	−0.5+1/4		
De	0+6/7	−0.5+0.5	−1+0.2			
Ef	−1+3/7					
abc	3+3	2.5+2.5	2+2	1.5+1.5	1+1	Panel length divided by depth of truss.
BC, *cd*	5+5	4.0+4.0	3+3	2.0+2.0	1+1	
CDE, *de*	6+6	4.5+4.5				
Thro. Deck						
Cc	2+15/7	1.5+10/6	1+1.2	0.5+3/4		Unity.
Cc, *Dd*	1+10/7	0.5+1.0	0+0.6	−0.5+1/4		
Dd	0+6/7	−0.5+0.5				

AXIMUM STRESSES UNDER DEAD AND MOVING LOADS IN WHIPPLE OR DOUBLE QUADRANGULAR TRUSSES, WITH INCLINED END POSTS AND EQUAL PANELS, FOR THROUGH AND DECK BRIDGES.

W = dead load and L = moving load per truss and per panel.

ember.	20-panel Truss.	19-panel Truss.	18-panel Truss.	17-panel Truss.	16-panel Truss.
	$W+L$	$W+L$	$W+L$	$W+L$	$W+L$
aB	[1] $9.5+9.5$	[1] $9+9$	[1] $8.5+8.5$	[1] $8+8$	[1] $7.5+7.5$
Bc	$4.5+\frac{90\cdot5}{20}$	$\frac{80}{19}+\frac{80\cdot5}{19}$	$4.0+\frac{72\cdot5}{18}$	$\frac{63}{17}+\frac{63\cdot5}{17}$	$3.5+\frac{56\cdot5}{16}$
Bd	$4.0+\frac{80\cdot5}{20}$	$\frac{72}{19}+\frac{72\cdot5}{19}$	$3.5+\frac{63\cdot5}{18}$	$\frac{56}{17}+\frac{56\cdot5}{17}$	$3.0+\frac{48\cdot5}{16}$
Ce	$3.5+\frac{72\cdot5}{20}$	$\frac{61}{19}+\frac{63\cdot5}{19}$	$3.0+\frac{56\cdot5}{18}$	$\frac{46}{17}+\frac{48\cdot5}{17}$	$2.5+\frac{42\cdot5}{16}$
Df	$3.0+\frac{63\cdot5}{20}$	$\frac{53}{19}+\frac{56\cdot5}{19}$	$2.5+\frac{48\cdot5}{18}$	$\frac{39}{17}+\frac{42\cdot5}{17}$	$2.0+\frac{35\cdot5}{16}$
Eg	$2.5+\frac{56\cdot5}{20}$	$\frac{42}{19}+\frac{48\cdot5}{19}$	$2.0+\frac{42\cdot5}{18}$	$\frac{29}{17}+\frac{35\cdot5}{17}$	$1.5+\frac{30\cdot5}{16}$
Fh	$2.0+\frac{48\cdot5}{20}$	$\frac{34}{19}+\frac{42\cdot5}{19}$	$1.5+\frac{35\cdot5}{18}$	$\frac{22}{17}+\frac{30\cdot5}{17}$	$1.0+\frac{24\cdot5}{16}$
Gi	$1.5+\frac{42\cdot5}{20}$	$\frac{23}{19}+\frac{35\cdot5}{19}$	$1.0+\frac{30\cdot5}{18}$	$\frac{12}{17}+\frac{24\cdot5}{17}$	$0.5+\frac{20\cdot5}{16}$
Hk	$1.0+\frac{35\cdot5}{20}$	$\frac{15}{19}+\frac{30\cdot5}{19}$	$0.5+\frac{24\cdot5}{18}$	$\frac{5}{17}+\frac{20\cdot5}{17}$	$0.0+\frac{15\cdot5}{16}$
Il	$0.5+\frac{30\cdot5}{20}$	$\frac{4}{19}+\frac{24\cdot5}{19}$	$0.0+\frac{20\cdot5}{18}$	$-\frac{5}{17}+\frac{15\cdot5}{17}$	$-0.5+\frac{12\cdot5}{16}$
Km	$0.0+\frac{24\cdot5}{20}$	$-\frac{4}{19}+\frac{20\cdot5}{19}$	$-0.5+\frac{15\cdot5}{18}$	$-\frac{12}{17}+\frac{12\cdot5}{17}$	$-1.0+\frac{8\cdot5}{16}$
Ln	$-0.5+\frac{20\cdot5}{20}$	$-\frac{15}{19}+\frac{15\cdot5}{19}$	$-1.0+\frac{12\cdot5}{18}$	$-\frac{22}{17}+\frac{8\cdot5}{17}$	$-1.5+\frac{6\cdot5}{16}$
Mo	$-1.0+\frac{15\cdot5}{20}$	$-\frac{23}{19}+\frac{12\cdot5}{19}$			
abc	[2] $9.5+9.5$	[2] $9+9$	[2] $8.5+8.5$	[2] $8+8$	[2] $7.5+7.5$
cd	$14+14$	$\frac{251}{19}+\frac{251}{19}$	$12.5+12.5$	$\frac{199}{17}+\frac{199}{17}$	$11+11$
C, de	$22+22$	$\frac{395}{19}+\frac{395}{19}$	$19.5+19.5$	$\frac{311}{17}+\frac{311}{17}$	$17+17$
D, ef	$29+29$	$\frac{517}{19}+\frac{517}{19}$	$25.5+25.5$	$\frac{403}{17}+\frac{403}{17}$	$22+22$
E, fg	$35+35$	$\frac{623}{19}+\frac{623}{19}$	$30.5+30.5$	$\frac{481}{17}+\frac{481}{17}$	$26+26$
F, gh	$40+40$	$\frac{707}{19}+\frac{707}{19}$	$34.5+34.5$	$\frac{539}{17}+\frac{539}{17}$	$29+29$
G, hi	$44+44$	$\frac{775}{19}+\frac{775}{19}$	$37.5+37.5$	$\frac{583}{17}+\frac{583}{17}$	$31+31$
H, ik	$47+47$	$\frac{821}{19}+\frac{821}{19}$	$39.5+39.5$	$\frac{607}{17}+\frac{607}{17}$ [1]	$32+32$
I, kl	$49+49$	$\frac{851}{19}+\frac{851}{19}$ [1]	$40.5+40.5$	$\frac{617}{17}+\frac{617}{17}$	$HI=GH$
KL	$50+50$	$\frac{859}{19}+\frac{859}{19}$	$IK=HI$	$IK=HI$	
		[1] $kl=\frac{843}{19}+\frac{843}{19}$		[1] $ik=\frac{597}{17}+\frac{597}{17}$	
hro. Deck					
Cc	[3] $4.5+\frac{90\cdot5}{20}$	[3] $\frac{80}{19}+\frac{80\cdot5}{19}$	[3] $4.0+\frac{72\cdot5}{18}$	[3] $\frac{63}{17}+\frac{63\cdot5}{17}$	[3] $3.5+\frac{56\cdot5}{16}$
Dd	$4.0+\frac{80\cdot5}{20}$	$\frac{72}{19}+\frac{72\cdot5}{19}$	$3.5+\frac{63\cdot5}{18}$	$\frac{56}{17}+\frac{56\cdot5}{17}$	$3.0+\frac{48\cdot5}{16}$
c, Ee	$3.5+\frac{72\cdot5}{20}$	$\frac{61}{19}+\frac{63\cdot5}{19}$	$3.0+\frac{56\cdot5}{18}$	$\frac{46}{17}+\frac{48\cdot5}{17}$	$2.5+\frac{42\cdot5}{16}$
d, Ff	$3.0+\frac{63\cdot5}{20}$	$\frac{53}{19}+\frac{56\cdot5}{19}$	$2.5+\frac{48\cdot5}{18}$	$\frac{39}{17}+\frac{42\cdot5}{17}$	$2.0+\frac{35\cdot5}{16}$
e, Gg	$2.5+\frac{56\cdot5}{20}$	$\frac{42}{19}+\frac{48\cdot5}{19}$	$2.0+\frac{42\cdot5}{18}$	$\frac{29}{17}+\frac{35\cdot5}{17}$	$1.5+\frac{30\cdot5}{16}$
f, Hh	$2.0+\frac{48\cdot5}{20}$	$\frac{34}{19}+\frac{42\cdot5}{19}$	$1.5+\frac{35\cdot5}{18}$	$\frac{22}{17}+\frac{30\cdot5}{17}$	$1.0+\frac{24\cdot5}{16}$
g, Ii	$1.5+\frac{42\cdot5}{20}$	$\frac{23}{19}+\frac{35\cdot5}{19}$	$1.0+\frac{30\cdot5}{18}$	$\frac{12}{17}+\frac{24\cdot5}{17}$	$0.5+\frac{20\cdot5}{16}$
h, Kk	$1.0+\frac{35\cdot5}{20}$	$\frac{15}{19}+\frac{30\cdot5}{19}$	$0.5+\frac{24\cdot5}{18}$	$\frac{5}{17}+\frac{20\cdot5}{17}$	$0.0+\frac{15\cdot5}{16}$
, Ll	$0.5+\frac{30\cdot5}{20}$	$\frac{4}{19}+\frac{24\cdot5}{19}$	$0.0+\frac{20\cdot5}{18}$	$-\frac{5}{17}+\frac{15\cdot5}{17}$	$-0.5+\frac{12\cdot5}{16}$
k	$0.0+\frac{24\cdot5}{20}$	$-\frac{4}{19}+\frac{20\cdot5}{19}$	$-0.5+\frac{15\cdot5}{18}$		
l	$-0.5+\frac{20\cdot5}{20}$				

[1] Multiply by: Length of member divided by depth of truss.
[2] Multiply by: Panel length divided by depth of truss.
[3] Multiply by: Unity.

MAXIMUM STRESSES UNDER DEAD AND MOVING LOADS I[N] WHIPPLE OR DOUBLE QUADRANGULAR TRUSSES, WITH IN[-]CLINED END POSTS AND EQUAL PANELS, FOR THROUG[H] AND DECK BRIDGES—(*Continued*).

W = dead load and L = moving load per truss and per panel.

Member.	15-panel Truss.	14-panel Truss.	13-panel Truss.	12-panel Truss.	11-panel Truss.
	$W+L$	$W+L$	$W+L$	$W+L$	$W+L$
aB	[1] 7+7	[1] 6.5+6.5	[1] 6+6	[1] 5.5+5.5	[1] 5+5
Bc	48/15 + 48·5/15	3.0 + 42·5/14	35/13 + 35·5/13	2.5 + 30·5/12	24/11 + 24·5/
Bd	42/15 + 42·5/15	2.5 + 35·5/14	30/13 + 30·5/13	2.0 + 24·5/12	20/11 + 20·5/
Ce	33/15 + 35·5/15	2.0 + 30·5/14	22/13 + 24·5/13	1.5 + 20·5/12	13/11 + 15·5/
Df	27/15 + 30·5/15	1.5 + 24·5/14	17/13 + 20·5/13	1.0 + 15·5/12	9/11 + 12·5/
Eg	18/15 + 24·5/15	1.0 + 20·5/14	9/13 + 15·5/13	0.5 + 12·5/12	2/11 + 8·5/
Fh	12/15 + 20·5/15	0.5 + 15·5/14	4/13 + 12·5/13	0.0 + 8·5/12	− 2/11 + 6·5/
Gi	3/15 + 15·5/15	0.0 + 12·5/14	− 4/13 + 8·5/13	−0.5 + 6·5/12	− 9/11 + 3·5/
Hk	− 3/15 + 12·5/15	−0.5 + 8·5/14	− 9/13 + 6·5/13	−1.0 + 3·5/12	−13/11 + 2·5/
Il	−12/15 + 8·5/15	−1.0 + 6·5/14	−17/13 + 3·5/13		
Km	−18/15 + 6·5/15				
abc	[2] 7+7	[2] 6.5+ 6.5	[2] 6+6	[2] 5.5+ 5.5	[2] 5+5
cd	153/15 + 153/15	9.5+ 9.5	113/13 + 113/13	8.0+ 8.0	79/11 + 79/
BC, de	237/15 + 237/15	14.5+14.5	173/13 + 173/13	12.0+12.0	119/11 + 119/
CD, ef	303/15 + 303/15	18.5+18.5	217/13 + 217/13	15.0+15.0	145/11 + 145/
DE, fg	357/15 + 357/15	21.5+21.5	251/13 + 251/13	17.0+17.0	163/11 + 163/
EF, gh	393/15 + 393/15	23.5+23.5	269/13 + 269/13 [1]	18.0+18.0	167/11 + 167/
FG, hi	417/15 + 417/15 [1]	24.5+24.5	277/13 + 277/13	*FG* = *EF*	*FG* = *EF*
GHI	423/15 + 423/15	*GH* = *FG*	*GH* = *FG*		[1] *fg* =
	[1] *hi* =		[1] *gh* =		159/11 + 159/
	411/15 + 411/15		261/13 + 261/13		
Thro. Deck					
Cc	[3] 48/15 + 48·5/15	[3] 3.0 + 42·5/14	[3] 35/13 + 35·5/13	[3] 2.5 + 30·5/12	[3] 24/11 + 24·5/
Dd	42/15 + 42·5/15	2.5 + 35·5/14	30/13 + 30·5/13	2.0 + 24·5/12	20/11 + 20·5/
Cc, Ee	33/15 + 35·5/15	2.0 + 30·5/14	22/13 + 24·5/13	1.5 + 20·5/12	13/11 + 15·5/
Dd, Ff	27/15 + 30·5/15	1.5 + 24·5/14	17/13 + 20·5/13	1.0 + 15·5/12	9/11 + 12·5/
Ee, Gg	18/15 + 24·5/15	1.0 + 20·5/14	9/13 + 15·5/13	0.5 + 12·5/12	2/11 + 8·5/
Ff, Hh	12/15 + 20·5/15	0.5 + 15·5/14	4/13 + 12·5/13	0.0 + 8·5/12	−2/11 + 6·5/
Gg	3/15 + 15·5/15	0.0 + 12·5/14	−4/13 + 8·5/13	−0.5 + 6·5/12	
Hh	−3/15 + 12·5/15	−0.5 + 8·5/14			

[1] Multiply by: Length of member divided by depth of truss.
[2] Multiply by: Panel length divided by depth of truss.
[3] Multiply by: Unity.

Resistance to Shearing.—By shearing is meant the separating and pushing of one part of a piece by the other.

To find the working shearing strength of wood: Find the area to be sheared in inches and multiply by the strength given in table on page 317.

For the compression and tensile strength proceed in like manner.

PART VI.

HYDRAULICS AND DATA ON WATER. STRENGTHS, WEIGHTS, ETC., OF MATERIALS. VARIOUS MATERIALS AND DATA.

Hydraulics.

TABLE SHOWING CAPACITIES OF CENTRIFUGAL PUMPS, ALSO USEFUL DATA REGARDING SAME.

Size Pump (Diameter Discharge Pipe).	Size Pipe for Suction, Inches.	Economical Capacity, Gallons per Minute.	Horse-Power Required for each Foot Elevation.	Diameter and Face of Pulley in Inches.
1½	2	70	.058	6× 6
1¾	2	90	.075	7× 8
2	3	120	.10	8× 8
2½	3	180	.15	8× 8
3	4	260	.22	8× 8
4	5	470	.30	10×10
5	6	735	.45	12×12
6	8	1050	.59	15×12
8	10	2000	1.00	20×12
10	12	3000	1.52	24×12
12	15	4200	2.00	30×14
15	18	7000	3.50	40×15
15	18	7000	3.50	30×15
18	20	10000	4.50	40×16
18	20	10000	4.50	30×16
20	22	12000	5.40	36×20
22	24	13000	5.50	48×20
24	24	15000	6.50	48×36

CAPACITY OF SAND AND DREDGING CENTRIFUGAL PUMPS.

No. Pump (Diameter Discharge Opening)	Diameter Suction.	Cubic Yards Material per Hour, 10 to 20 Per Cent of Solids.			Horsepower Required for each 10 Feet Elevation.	Will Pass Solids: Diameter, Inches.	Diameter and Face of Pulley.
		10 Per Cent.	15 Per Cent.	20 Per Cent.			
4	4	14	21	28	4	2	12×12
6	6	30	45	60	8	4½	20×12
8	8	60	90	120	15	6	24×14
10	10	90	135	180	25	8	30×15
12	12	125	190	250	30	10	36×20
15	15	210	315	420	50	10	42×24
18	18	300	450	600	70	10	48×30

REVOLUTION TABLE

Speeds at which Standard Pumps should Run to Raise Water to Different Heights.

No.	5 Ft.	10 Ft.	15 Ft.	25 Ft.	35 Ft.	50 Ft.	70 Ft.	100 Ft.
$1\frac{1}{2}$	428	604	739	955	1131	1351	1599	1911
$1\frac{3}{4}$	348	491	601	777	920	1099	1301	1554
2	302	426	522	674	798	953	1128	1348
$2\frac{1}{2}$	302	426	522	674	798	953	1128	1348
3	302	426	522	674	798	953	1128	1348
4	285	402	493	637	754	901	1066	1274
5	256	362	443	572	678	810	958	1145
6	214	302	368	478	566	675	800	955
8	183	259	317	409	485	579	685	819
10	168	238	291	376	445	532	629	752
12	133	188	230	298	352	421	498	595
15	105	148	181	234	277	331	391	468
15	151	213	261	337	399	477	564	674
18	105	148	181	234	277	331	391	468
18	151	213	261	337	399	477	564	674
20	142	202	245	317	376	450	532	635
24	95	134	163	212	252	300	355	424

If water is to be forced through long pipes or through many elbows, speed must be increased to correspond.

Weir-dam Measurement for Flow of Water in Streams.—Cut a notch in a board deep enough to pass all the water and about two-thirds the width of the stream,

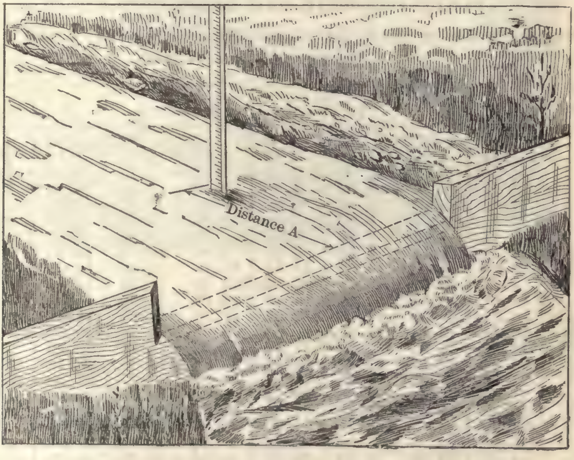


FIG. 353.

as shown by Fig. 353. Bevel the edges of the notch, then secure it in the position shown in the above view. Drive a stake

in the bottom of the stream about 4 or 5 feet from the board (shown as distance A in the view). The top of the stake must be exactly level with the bottom of the notch in the board. After the water has come to an even flow and reached its greatest depth, a careful measurement can be made of the depth of the water over the top of the stake. This measurement gives the true depth of water passing over notch. On the downward side, the water must have a drop of 10 to 15 inches after leaving the board to enable you to get the true flow.

The nature of the channel above the board should be such that the water will not rush over the board, but should be wide and deep enough to allow it to flow over quietly.

The Weir-dam table given below shows the number of cubic feet of water passing per minute over the notch for each inch in breadth. The figures in the first vertical column are the inches depth of water over the weir. The figures on first horizontal line show fractional parts of inches depth. The table shows cubic feet that will pass per minute per inch of width of notch in board.

Example.—Suppose the notch in the board is 20 inches wide and the water is 5½ inches above top of stake. In the table

TABLE FOR WEIR-DAM MEASUREMENT,

Giving cubic feet of water per minute that will flow over a weir 1 inch wide and up to 25 inches deep.

Inch.		⅛	¼	⅜	½	⅝	¾	⅞
1	.40	.47	.55	.65	.74	.83	.93	1.03
2	1.14	1.24	1.36	1.47	1.59	1.71	1.83	1.96
3	2.09	2.23	2.36	2.50	2.63	2.78	2.92	3.07
4	3.22	3.37	3.52	3.68	3.83	3.99	4.16	4.32
5	4.50	4.67	4.84	5.01	5.18	5.36	5.54	5.72
6	5.90	6.09	6.28	6.47	6.65	6.85	7.05	7.25
7	7.44	7.64	7.84	8.05	8.25	8.45	8.66	8.86
8	9.10	9.31	9.52	9.74	9.96	10.18	10.40	10.62
9	10.86	11.08	11.31	11.54	11.77	12.00	12.23	12.47
10	12.71	12.95	13.19	13.43	13.67	13.93	14.16	14.42
11	14.67	14.92	15.18	15.43	15.67	15.96	16.20	16.46
12	16.73	16.99	17.26	17.52	17.78	18.05	18.32	18.58
13	18.87	19.14	19.42	19.69	19.97	20.24	20.52	20.80
14	21.09	21.37	21.65	21.94	22.22	22.51	22.79	23.08
15	23.38	23.67	23.97	24.26	24.56	24.86	25.16	25.46
16	25.76	26.06	26.36	26.66	26.97	27.27	27.58	27.89
17	28.20	28.51	28.82	29.14	29.45	29.76	30.08	30.39
18	30.70	31.02	31.34	31.66	31.98	32.31	32.63	32.96
19	33.29	33.61	33.94	34.27	34.60	34.94	35.27	35.60
20	35.94	36.27	36.60	36.94	37.28	37.62	37.96	38.31
21	38.65	39.00	39.34	39.69	40.04	40.39	40.73	41.09
22	41.43	41.78	42.13	42.49	42.84	43.20	43.56	43.92
23	44.28	44.64	45.00	45.38	45.71	46.08	46.43	46.81
24	47.18	47.55	47.91	48.28	48.65	49.02	49.39	49.76

$5\frac{1}{2}$ inches show that 5.18 cubic feet flow over 1 inch of width. Multiply this by 20 (width of notch), and you will have 103.6, which represents the cubic feet of water passing over the weir, or amount in the stream. This multiplied by $7\frac{1}{2}$ will give the gallons.

A "miners' inch" of water is approximately equal to a supply of 12 United States gallons per minute.

Measurements of Large Streams.—Where measurement by weir is impracticable, the amount of water can be calculated by ascertaining the average velocity of the current and the cross-section of the stream.

Select a place in the stream where there is a moderate current, or smooth, even flow of water, and measure the depth of the water at from 6 to 12 points across the stream at equal

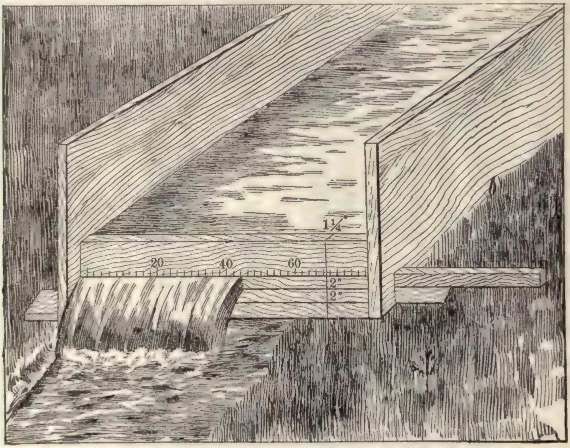


FIG. 354.

distances between. Add all the depths in feet together, and divide by the number of measurements made; this will be the average depth of the stream, which, multiplied by its width, will give its area or cross-section. Multiply this by the velocity of the stream in feet per minute, and the result will be the discharge in cubic feet per minute of the stream.

Miners' Inch Measurement.—The miners' inch is another method of measuring flow of water, and is commonly

used by the hydraulic companies in the western part of the United States.

The standard opening is 50 inches long by 2 inches wide in a 1¼-inch board, top of said opening being 6 inches from level of water in stream, as shown by Fig. 354. This is equivalent to 100 miners' inches, and will discharge 157 cubic feet per minute, commonly taken as 150 cubic feet.

If there is not 150 cubic feet in the stream, it will be necessary to close part of the longitudinal 2-inch opening, so that the water will stand 6 inches above the upper edge of the slot at all times. The length of the opening multiplied by two gives the number of miners' inches.

PRESSURE OF WATER.

Head in Feet.	Pressure in Pounds per Square Inch.	Head in Feet.	Pressure in Pounds per Square Inch.	Head in Feet.	Pressure in Pounds per Square Inch.	Head in Feet.	Pressure in Pounds per Square Inch
1	0.43	34	14.74	67	29.05	100	43.35
2	0.87	35	15.17	68	29.48	101	43.78
3	1.30	36	15.61	69	29.91	102	44.22
4	1.73	37	16.04	70	30.35	103	44.65
5	2.17	38	16.47	71	30.78	104	45.08
6	2.60	39	16.91	72	31.21	105	45.52
7	3.03	40	17.34	73	31.65	106	45.95
8	3.47	41	17.77	74	32.08	107	46.39
9	3.90	42	18.21	75	32.51	108	46.82
10	4.34	43	18.64	76	32.95	109	47.25
11	4.77	44	19.07	77	33.38	110	47.69
12	5.20	45	19.51	78	33.81	111	48.12
13	5.64	46	19.94	79	34.25	112	48.55
14	6.07	47	20.37	80	34.68	113	48.99
15	6.50	48	20.81	81	35.11	114	49.42
16	6.94	49	21.24	82	35.55	115	49.85
17	7.37	50	21.68	83	35.98	116	50.29
18	7.80	51	22.11	84	36.41	117	50.72
19	8.24	52	22.54	85	36.85	118	51.15
20	8.67	53	22.98	86	37.28	119	51.59
21	9.10	54	23.41	87	37.72	120	52.02
22	9.54	55	23.84	88	38.15	121	52.45
23	9.97	56	24.28	89	38.58	122	52.89
24	10.40	57	24.71	90	39.02	123	53.32
25	10.84	58	25.14	91	39.45	124	53.75
26	11.27	59	25.58	92	39.88	125	54.19
27	11.70	60	26.01	93	40.32	126	54.62
28	12.14	61	26.44	94	40.75	127	55.06
29	12.57	62	26.88	95	41.18	128	55.49
30	13.01	63	27.31	96	41.62	129	55.92
31	13.44	64	27.74	97	42.05	130	56.36
32	13.87	65	28.18	98	42.48	131	56.79
33	14.31	66	28.61	99	42.92	132	57.22

PRESSURE OF WATER—(*Continued*).

Head in Feet.	Pressure in Pounds per Sq. Inch.	Head in Feet.	Pressure in Pounds per Sq. Inch.	Head in Feet.	Pressure in Pounds per Sq. Inch.	Head in Feet.	Pressure in Pounds per Sq. Inch.
133	57.66	175	75.86	217	94.06	259	112.27
134	58.09	176	76.30	218	94.50	260	112.71
135	58.52	177	76.73	219	94.93	261	113.14
136	58.96	178	77.16	220	95.37	262	113.57
137	59.39	179	77.60	221	95.80	263	114.01
138	59.82	180	78.03	222	96.23	264	114.44
139	60.26	181	78.46	223	96.67	265	114.87
140	60.69	182	78.90	224	97.10	266	115.31
141	61.12	183	79.33	225	97.53	267	115.74
142	61.56	184	79.77	226	97.97	268	116.17
143	62.00	185	80.20	227	98.40	269	116.61
144	62.43	186	80.63	228	98.83	270	117.04
145	62.86	187	81.07	229	99.27	271	117.47
146	63.29	188	81.50	230	99.70	272	117.91
147	63.73	189	81.93	231	100.13	273	118.34
148	64.16	190	82.37	232	100.56	274	118.77
149	64.59	191	82.80	233	101.00	275	119.21
150	65.03	192	83.23	234	101.43	276	119.64
151	65.46	193	83.67	235	101.86	277	120.07
152	65.89	194	84.10	236	102.30	278	120.51
153	66.33	195	84.53	237	102.73	279	120.94
154	66.76	196	84.97	238	103.16	280	121.38
155	67.19	197	85.40	239	103.60	281	121.81
156	67.63	198	85.83	240	104.03	282	122.24
157	68.06	199	86.27	241	104.46	283	122.68
158	68.49	200	86.70	242	104.90	284	123.11
159	68.93	201	87.13	243	105.33	285	123.54
160	69.36	202	87.56	244	105.76	286	123.98
161	69.79	203	88.00	245	106.20	287	124.41
162	70.23	204	88.43	246	106.63	288	124.84
163	70.66	205	88.85	247	107.06	289	125.28
164	71.10	206	89.30	248	107.50	290	125.71
165	71.53	207	89.73	249	107.93	291	126.14
166	71.96	208	90.15	250	108.37	292	126.58
167	72.40	209	90.60	251	108.80	293	127.01
168	72.83	210	91.03	252	109.23	294	127.44
169	73.26	211	91.46	253	109.67	295	127.88
170	73.70	212	91.90	254	110.10	296	128.31
171	74.13	213	92.33	255	110.53	297	128.74
172	74.56	214	92.76	256	110.97	298	129.18
173	75.00	215	93.20	257	111.40	299	129.61
174	75.43	216	93.63	258	111.83	300	130.05

VELOCITY OF WATER.

Table giving velocity of water in feet per second, and the cubic feet of water per minute, to develop one horse-power at 80 per cent duty under heads from 1 to 108 feet.

Head	Velocity.	Cubic Feet.	Head	Velocity.	Cubic Feet.	Head	Velocity.	Cubic Feet.
1	8.02	661.765	37	48.78	17.886	73	68.53	9.065
2	11.34	330.883	38	49.44	17.415	74	69.00	8.943
3	13.89	220.589	39	50.09	16.968	75	69.46	8.822
4	16.04	165.441	40	50.72	16.544	76	69.92	8.707
5	17.92	132.353	41	51.35	16.141	77	70.38	8.594
6	19.65	110.294	42	54.98	15.756	78	70.84	8.484
7	21.22	94.538	43	52.59	15.390	79	71.29	8.377
8	22.68	82.720	44	53.20	15.040	80	71.74	8.272
9	24.06	73.529	45	53.80	14.706	81	72.19	8.170
10	25.36	66.177	46	54.40	14.368	82	72.63	8.070
11	26.60	60.160	47	54.99	14.080	83	73.07	7.973
12	27.78	55.147	48	55.57	13.787	84	73.51	7.878
13	28.92	50.905	49	56.14	13.505	85	73.95	7.785
14	30.01	47.269	50	56.71	13.236	86	74.38	7.695
15	31.06	44.118	51	57.27	12.976	87	74.81	7.606
16	32.08	41.360	52	57.84	12.726	88	75.24	7.520
17	33.07	38.927	53	58.39	12.486	89	75.67	7.436
18	34.03	36.765	54	58.93	12.255	90	76.09	7.353
19	34.96	34.830	55	59.48	12.032	91	76.51	7.272
20	35.87	33.088	56	60.01	11.817	92	76.93	7.193
21	36.75	31.513	57	60.56	11.610	93	77.35	7.116
22	37.61	30.080	58	61.08	11.410	94	77.76	7.040
23	38.46	28.772	59	61.61	11.216	95	78.18	6.966
24	39.29	27.574	60	62.12	11.029	96	78.59	6.893
25	40.10	26.471	61	62.71	10.849	97	79.00	6.822
26	40.89	25.453	62	63.15	10.674	98	79.40	6.753
27	41.67	24.510	63	63.66	10.504	99	79.81	6.685
28	42.44	23.634	64	64.16	10.340	100	80.22	6.618
29	43.19	22.819	65	64.66	10.181	101	80.61	6.552
30	43.93	22.059	66	65.16	10.027	102	81.01	6.487
31	44.65	21.347	67	65.65	9.877	103	81.40	6.425
32	45.37	20.680	68	66.14	9.732	104	81.80	6.363
33	46.07	20.053	69	66.62	9.591	105	82.19	6.303
34	46.77	19.464	70	67.11	9.454	106	82.58	6.243
35	47.45	18.908	71	67.58	9.321	107	82.97	6.185
36	48.12	18.382	72	68.06	9.191	108	83.35	6.127

TABLE SHOWING FLOW OF WATER THROUGH NOZZLES.

Quantity and Horse-power.

Head, Feet.	Velocity per Second, Feet.	Diameters of Nozzles. 1 Inch.		1.5 Inches.		2 Inches.		2.5 Inches.		3 Inches.	
		Cubic Feet per Second.	Horse-power.	Cubic Feet per Second.	Horse-power.	Cubic Feet per Second.	Horse-power.	Cubic Feet per Second.	Horse-power.	Cubic Feet per Second.	Horse-power.
5	17.95	.091	.051	.205	.113	.364	.204	.56	.315	.820	.452
10	25.38	.129	.146	.290	.329	.516	.584	.805	.915	1.16	1.32
15	31.08	.158	.269	.355	.505	.632	1.08	.985	1.68	1.42	2.42
20	35.89	.182	.414	.410	.931	.728	1.66	1.14	2.58	1.64	3.72
25	40.13	.204	.578	.458	1.30	.816	2.31	1.27	3.61	1.83	5.20
30	43.95	.228	.760	.513	1.71	.912	3.04	1.42	4.75	2.05	6.84
35	47.47	.241	.958	.542	2.15	.964	3.83	1.51	5.98	2.17	8.60
40	50.75	.257	1.17	.579	2.63	1.03	4.68	1.61	7.31	2.32	10.52
45	53.83	.273	1.40	.614	3.14	1.09	5.60	1.71	8.23	2.46	12.56
50	56.75	.288	1.64	.648	3.68	1.15	6.56	1.79	10.22	2.59	14.72
60	62.16	.385	2.15	.709	4.84	1.26	8.60	1.97	13.43	2.84	19.36
70	67.14	.341	2.71	.766	6.10	1.36	10.84	2.13	16.93	3.06	24.40
80	71.78	.364	3.31	.819	7.45	1.46	13.24	2.27	20.69	3.28	20.80
90	76.13	.386	3.95	.864	8.88	1.54	15.80	2.44	24.68	3.46	35.52
100	80.25	.407	4.63	.916	10.41	1.63	18.52	2.54	28.90	3.66	41.64
125	89.72	.455	6.47	1.02	14.55	1.82	25.88	2.81	40.40	4.08	58.20
150	98.28	.499	8.50	1.12	19.12	2.00	34.00	3.11	53.12	4.48	76.48
175	106.1	.539	10.70	1.21	24.07	2.16	42.80	3.36	66.86	4.84	96.28
200	113.5	.576	13.1	1.29	29.43	2.30	52.4	3.50	81.75	5.10	117.7
250	127.1	.644	18.3	1.45	41.13	2.58	73.2	4.02	114.2	5.80	164.5
300	139.0	.705	24.0	1.59	54.07	2.82	96.0	4.40	150.2	6.36	216.3
350	150.1	.762	30.3	1.71	68.15	3.05	121.2	4.76	189.3	6.84	272.6
400	160.5	.814	37.0	1.83	83.25	3.26	148.0	5.09	231.2	7.32	323.0
450	170.2	.864	44.2	1.94	99.34	3.46	176.8	5.40	276.0	7.76	397.4
500	179.4	.910	51.7	2.05	116.5	3.64	206.8	5.60	323.2	8.20	406.0
550	188.2	.955	59.7	2.10	134.2	3.82	238.8	5.96	372.7	8.40	536.8
600	196.6	.999	68.0	2.23	152.9	3.99	272.0	6.23	475.0	8.92	611.0
700	212.3	1.06	85.7	2.46	192.8	4.36	342.8	6.79	535.5	9.84	771.2
800	226.9	1.15	104.7	2.58	235.5	4.60	418.8	7.19	654.0	10.32	942.0
900	240.7	1.22	124.9	2.75	281.0	4.88	499.6	7.63	780.5	11.00	1124
1000	253.8	1.29	146.2	2.89	329.0	5.16	584.8	8.04	914.0	11.56	1316

FIRE STREAMS.

Pressures required at nozzle and at pump, with quantity and pressure of water necessary to throw water various distances through different-sized nozzles—using 2½-inch rubber hose and smooth nozzles.—G. A. ELLIS, C.E.

Size of Nozzles.	1 Inch.				1⅛ Inch.			
Pressure at nozzle.	40	60	80	100	40	60	80	100
* Pressure at pump or hydrant with 100 ft. 2½-inch rubber hose.	48	73	97	121	54	81	108	135
Gallons per minute.	155	189	219	245	196	240	277	310
Horizontal distance thrown.	109	142	168	186	113	148	175	193
Vertical dist. thrown.	79	108	131	148	81	112	137	157

Size of Nozzles.	1¼ Inch.				1⅜ Inch.			
Pressure at nozzle.	40	60	80	100	40	60	80	100
* Pressure at pump or hydrant with 100 ft. 2½-inch rubber hose.	61	92	123	154	71	107	144	180
Gallons per minute.	242	297	342	383	293	358	413	462
Horizontal distance thrown.	118	156	186	207	124	166	200	224
Vertical dist. thrown.	82	115	142	164	85	118	146	169

* For greater lengths of 2½ hose the increased friction can readily be obtained by noting the differences between the above given "pressure at nozzle" and "pressure at pump or hydrant with 100 *feet* of hose." For instance, if it requires at hydrant or pump 8 lbs. more pressure than it does at nozzle to overcome the friction when pumping through 100 feet of 2½-inch hose (using 1-inch nozzle, with 40 lbs. pressure at said nozzle), then it requires 16 lbs. pressure to overcome the friction in forcing through 200 feet of same size hose.

TABLE SHOWING FLOW OF WATER PER SECOND THROUGH CLEAN IRON PIPES.

Fall in Feet per 100 Feet of Pipe.	Diameters.								
	1 In. Cu. Ft.	2 In. Cu. Ft.	3 In. Cu. Ft.	4 In. Cu. Ft.	6 In. Cu. Ft.	8 In. Cu. Ft.	10 In. Cu. Ft.	11 In. Cu. Ft.	12 In. Cu. Ft.
.10	......	......	......	......	......	......	......	......	1.265
.12	......	......	......	......	......	......	.878	1.120	1.402
.14	......	......	......	......	......	......	.960	1.221	1.489
.16	......	......	......	......	......	.573	1.047	1.320	1.634
.18	......	......	......	......	......	.611	1.110	1.394	1.728
.20	......	......	......	......	.298	.639	1.194	1.490	1.846
.22	......	......	......	......	.314	.659	1.265	1.580	1.940
.24	......	......	......	......	.330	.703	1.325	1.653	2.026
.26	......	......	......	.1235	.346	.737	1.377	1.722	2.117
.28	......	......	......	.1298	.359	.768	1.423	1.788	2.207
.30	......	......	.0630	.1335	.377	.808	1.470	1.854	2.297
.35	......	......	.0692	.1465	.395	.876	1.587	1.996	2.466
.40	......	.02584	.0749	.1562	.444	.931	1.683	2.136	2.662
.50	......	.02924	.0839	.1771	.496	1.045	1.865	2.397	3.020
.60	......	.03274	.0915	.1923	.548	1.575	2.059	2.636	3.310
.70	......	.03492	.0992	.2146	.589	1.262	2.222	2.858	3.601
.80	.00567	.03776	.1060	.2339	.631	1.344	2.383	3.062	3.856
.90	.00617	.04081	.1119	.2460	.672	1.424	2.514	3.232	4.072
1.00	.00677	.04321	.1190	.2582	.721	1.496	2.662	3.419	4.305
1.20	.00781	.04843	.1313	.2893	.784	1.644	2.932	3.760	4.728
1.40	.00841	.05150	.1413	.3036	.858	1.782	3.210	4.016	5.094
1.60	.00886	.05456	.1507	.3237	.922	1.916	3.450	4.390	5.482
1.80	.00961	.05740	.1590	.3412	.975	2.033	3.679	4.679	5.839
2.00	.00990	.06111	.1717	.3607	1.022	2.155	3.856	5.251	6.160
3.00	.01245	.07399	.2081	.4503	1.263	2.667	4.762	6.086	7.630
4.00	.01492	.08734	.2469	.5331	1.484	3.145	5.563	7.022	8.860
5.00	.01666	.1095	.2785	.5954	1.665	3.513	6.704	8.244	9.967
6.00	.01857	.1200	.3049	.6390	1.929	3.847	......	......	......
7.00	.01988	.1288	.3331	.6967	1.976	4.196	......	......	......
8.00	.02141	.1375	.3559	.7506	2.144	......	......	......	......
9.00	.02283	.1442	.3816	.7960	2.274	......	......	......	......
10.00	.02424	.1523	.4043	.9464	2.399	......	......	......	......
12.00	.02676	.1634	.4440	.9270	......	......	......	......	......
14.00	.02890	.1748	.4977	1.0060	......	......	......	......	......
15.98	.03081	.1855	.5131	1.0810	......	......	......	......	......
18.00	.03276	.1955	.5436	......	......	......	......	......	......
20.00	.03458	.2047	.5832	......	......	......	......	......	......
25.00	.03897	.2276	.6523	......	......	......	......	......	......
30.00	.04316	.2483	......	......	......	......	......	......	......
40.00	.04987	.2833	......	......	......	......	......	......	......
50.00	.05648	......	......	......	......	......	......	......	......
60.00	.06320	......	......	......	......	......	......	......	......
70.00	.06943	......	......	......	......	......	......	......	......

To find the velocity in feet per second necessary to carry a given quan-ity of water in a pipe of given diameter, divide the quantity in cubic feet per second by the area of the pipe in square feet; the quotient will give the velocity.

TABLE SHOWING FLOW OF WATER PER SECOND THROUGH CLEAN IRON PIPES.

Fall in Feet per 100 Feet of Pipe.	Diameter.											
	14 In. Cu. Ft.	15 In. Cu. Ft.	16 In. Cu. Ft.	18 In. Cu. Ft.	20 In. Cu. Ft.	22 In. Cu. Ft.	24 In. Cu. Ft.	26 In. Cu. Ft.	30 In. Cu. Ft.	36 In. Cu. Ft.	40 In. Cu. Ft.	48 In. Cu. Ft.
.02	....	....	....	....	....	....	....	....	....	10.29	13.88	22.98
.03	....	....	....	....	....	....	....	....	7.78	12.70	17.00	27.89
.04	....	....	....	....	....	....	....	....	8.99	14.56	19.68	32.93
.05	....	....	....	....	....	....	....	7.48	10.24	16.35	22.08	37.00
.06	....	....	....	....	3.61	4.61	6.10	7.61	10.97	18.02	24.43	40.21
.07	....	....	2.25	3.10	4.07	5.25	6.64	8.27	11.90	19.76	26.27	43.67
.08	1.71	2.05	2.43	3.27	4.35	5.62	7.13	8.70	12.84	20.85	28.14	46.81
.09	1.83	2.19	2.59	3.49	4.68	6.01	7.56	9.36	13.48	22.30	29.80	49.06
.10	1.91	2.30	2.72	3.66	4.92	6.32	7.95	9.81	14.21	23.47	31.46	52.15
.11	2.02	2.43	2.88	3.88	5.15	6.62	8.34	10.44	15.05	24.91	33.25	54.95
.12	2.11	2.54	3.02	4.06	5.40	6.94	8.75	10.87	15.81	26.12	34.68	57.36
.13	2.18	2.65	3.18	4.23	5.62	7.24	9.14	11.41	16.47	27.20	36.21	60.07
.14	2.27	2.75	3.28	4.40	5.82	7.51	9.47	11.80	17.18	28.24	37.57	62.02
.15	2.35	2.84	3.39	4.61	6.05	7.78	9.80	12.26	17.94	29.19	39.18	64.47
.16	2.44	2.94	3.49	4.75	6.27	8.03	10.13	12.70	18.58	30.29	40.54	66.53
.17	2.54	2.98	3.62	4.90	6.48	8.36	10.57	13.13	19.21	31.42	41.88	68.50
.18	2.59	3.11	3.69	5.03	6.65	8.55	10.77	13.46	19.66	32.48	43.07	70.62
.19	2.67	3.21	3.81	5.17	6.92	8.85	11.10	13.84	20.32	33.40	44.28	72.75
.20	2.72	3.29	3.92	5.30	7.05	9.07	11.43	14.23	20.79	34.49	45.20	74.44
.22	2.88	3.47	4.12	5.63	7.42	9.55	12.05	14.98	21.80	36.15	48.12	78.29
.24	3.02	3.63	4.32	5.87	7.79	10.01	12.61	15.69	22.83	37.74	50.48	81.68
.26	3.15	3.79	4.51	6.18	8.14	10.48	13.23	16.42	23.93	39.40	52.67	85.20
.28	3.29	3.95	4.68	6.38	8.48	10.91	13.79	17.07	24.86	40.86	55.04	88.46
.30	3.42	4.11	4.87	6.64	8.77	11.29	14.25	17.75	25.87	42.28	56.33	91.73
.35	3.62	4.46	5.31	7.17	9.49	12.25	15.50	19.25	27.96	45.95	61.09	100.40
.40	3.99	4.78	5.67	7.65	10.16	13.12	16.62	20.62	29.84	48.83	65.41	105.89
.50	4.46	5.37	6.39	8.66	11.43	14.78	18.71	23.13	33.55	54.89	73.09	119.34
.60	4.91	5.91	7.02	9.54	12.59	16.20	20.42	25.30	36.79	59.95	80.32	130.88
.70	5.37	6.45	7.66	10.33	13.66	17.53	22.05	27.12	39.66	65.17	86.70	148.09
.80	5.77	6.90	8.16	11.09	14.66	18.78	23.61	29.20	42.39	69.80	92.58	153.49
.90	6.11	7.31	8.64	11.71	15.54	19.93	25.07	31.00	45.23	74.33	98.00	.....
1.00	6.44	7.70	9.10	12.37	16.47	21.06	26.42	32.73	47.71	78.46	103.99	.....
1.20	7.00	8.39	9.95	13.65	17.99	23.07	29.03	36.18	52.91	82.84	.....	.....
1.40	7.60	9.15	10.87	14.75	19.49	24.68	31.49	39.31	57.65	....	.....	.....
1.60	8.17	9.81	11.63	15.84	21.03	26.97	33.90	42.35	....	....	.....	.....
1.80	8.93	10.47	12.43	16.90	22.45	29.70	36.18	44.10	....	....	.....	.....
2.00	9.26	11.09	13.14	17.85	23.56	31.15	38.45	....	....	....	.....	.....
3.00	11.39	13.66	16.17	21.86	28.86	....	....	....	....	....	.....	.....
4.00	13.22	15.84	18.77	....	....	....	....	....	....	....	.....	.....

To find the area of a required pipe, the quantity and velocity being given, divide the quantity in a stated time by the velocity in the same period; the quotient will be the required area, from which the diameter may readily be calculated.

LOSS OF HEAD BY FRICTION.

The following tables give the friction head in pipe 1 to 12 inches diameter, per 100 feet length, with velocities from 2 to 7 feet per second.

INSIDE DIAMETER OF PIPE IN INCHES.

Velocity in Feet per Sec.	1		2		3		4	
	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.
2.0	2.37	.65	1.185	2.62	.791	5.89	.593	10.4
2.2	2.80	.73	1.404	2.88	.936	6.48	.702	11.5
2.4	3.27	.79	1.639	3.14	1.093	7.07	.819	12.5
2.6	3.78	.86	1.891	3.40	1.26	7.65	.945	13.6
2.8	4.32	.92	2.16	3.66	1.44	8.24	1.08	14.6
3.0	4.89	.99	2.44	3.92	1.62	8.83	1.22	15.7
3.2	5.47	1.06	2.73	4.18	1.82	9.42	1.37	16.7
3.4	6.09	1.12	3.05	4.45	2.04	10.00	1.52	17.8
3.6	6.76	1.19	3.38	4.71	2.26	10.60	1.69	18.8
3.8	7.48	1.26	3.74	4.97	2.49	11.20	1.87	19.9
4.0	8.20	1.32	4.10	5.23	2.73	11.80	2.05	20.9
4.2	8.97	1.39	4.49	5.49	2.98	12.30	2.24	22.0
4.4	9.77	1.45	4.89	5.76	3.25	12.90	2.43	23.0
4.6	10.60	1.52	5.30	6.02	3.53	13.50	2.64	24.0
4.8	11.45	1.58	5.72	6.28	3.81	14.10	2.85	25.1
5.0	12.33	1.65	6.17	6.54	4.11	14.70	3.08	26.2
5.2	13.24	1.72	6.62	6.80	4.41	15.30	3.31	27.2
5.4	14.20	1.78	7.10	7.06	4.73	15.90	3.55	28.2
5.6	15.16	1.85	7.58	7.32	5.06	16.50	3.79	29.3
5.8	16.17	1.91	8.09	7.58	5.40	17.10	4.04	30.3
6.0	17.23	1.98	8.61	7.85	5.74	17.70	4.31	31.4
7.0	22.89	2.31	11.45	9.16	7.62	20.60	5.72	36.6

INSIDE DIAMETER OF PIPE IN INCHES.

Velocity in Feet per Sec.	5		6		7		8	
	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.
2.0	.474	16.3	.395	23.5	.338	32.0	.96	41.9
2.2	.561	18.0	.468	25.9	.401	35.3	.351	46.1
2.4	.650	19.6	.547	28.2	.468	38.5	.410	50.2
2.6	.757	21.3	.631	30.6	.540	41.7	.473	54.4
2.8	.864	22.9	.720	32.9	.617	44.9	.540	58.6
3.0	.978	24.5	.815	35.3	.698	48.1	.611	62.8
3.2	1.098	26.2	.915	37.7	.785	51.3	.686	67.0
3.4	1.22	27.8	1.021	40.0	.875	54.5	.765	71.2
3.6	1.35	29.4	1.131	42.4	.969	57.7	.848	75.4
3.8	1.49	31.0	1.25	44.7	1.070	60.9	.936	79.6
4.0	1.64	32.7	1.37	47.1	1.175	64.1	1.027	83.7
4.2	1.79	34.3	1.49	49.5	1.28	67.3	1.122	87.9
4.4	1.95	36.0	1.62	51.8	1.39	70.5	1.22	92.1
4.6	2.11	37.6	1.76	54.1	1.51	73.7	1.32	96.3
4.8	2.27	39.2	1.90	56.5	1.63	76.9	1.43	100.0
5.0	2.46	40.9	2.05	58.9	1.76	80.2	1.54	105.0
5.2	2.65	42.5	2.21	61.2	1.89	83.3	1.65	109.0
5.4	2.84	44.2	2.37	63.6	2.03	86.6	1.77	113.0
5.6	3.03	45.8	2.53	65.9	2.17	89.8	1.89	117.0
5.8	3.24	47.4	2.70	68.3	2.31	93.0	2.01	121.0
6.0	3.45	49.1	2.87	70.7	2.46	96.2	2.15	125.0
7.0	4.57	57.2	3.81	82.4	3.26	112.0	2.85	146.0

LOSS OF HEAD BY FRICTION—(*Continued*).

INSIDE DIAMETER OF PIPE IN INCHES.

Velocity in Feet per Sec.	9		10		11		12	
	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.
2.0	.264	53	.237	65.4	.216	79.2	.198	94
2.2	.312	58.3	.281	72	.255	87.1	.234	103
2.4	.365	63.6	.327	78.5	.297	95.0	.273	113
2.6	.420	68.9	.378	85.1	.344	103	.315	122
2.8	.480	74.2	.432	91.6	.392	111	.360	132
3.0	.544	79.5	.488	98.2	.444	119	.407	141
3.2	.609	84.8	.549	105	.499	127	.457	151
3.4	.680	90.1	.612	111	.557	134	.510	160
3.6	.755	95.4	.679	118	.617	142	.566	169
3.8	.831	101	.749	124	.680	150	.624	179
4.0	.913	106	.822	131	.747	158	.685	188
4.2	.998	111	.897	137	.816	166	.749	198
4.4	1.086	116	.977	144	.888	174	.815	207
4.6	1.177	122	1.059	150	.963	182	.883	217
4.8	1.27	127	1.145	157	1.040	190	.954	226
5.0	1.37	132	1.23	163	1.122	198	1.028	235
5.2	1.47	138	1.32	170	1.20	206	1.104	245
5.4	1.57	143	1.41	177	1.28	214	1.183	254
5.6	1.68	148	1.51	183	1.37	222	1.26	264
5.8	1.80	154	1.61	190	1.46	229	1.34	273
6.0	1.92	159	1.71	196	1.56	237	1.43	283
7.0	2.52	185	2.28	229	2.07	277	1.91	330

The following tables give the friction head in pipe 13 to 36 inches' diameter, per 100 feet length with velocities of water from 2 to 7 feet per second.

INSIDE DIAMETER OF PIPE IN INCHES.

Velocity in Feet per Sec.	13		14		15		16	
	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.
2.0	.183	110	.169	128	.158	147	.147	167
2.2	.216	121	.200	141	.187	162	.175	184
2.4	.252	133	.234	154	.218	176	.205	201
2.6	.290	144	.270	167	.252	191	.236	218
2.8	.332	156	.308	179	.288	206	.270	234
3.0	.375	166	.349	192	.325	221	.306	251
3.2	.422	177	.392	205	.366	235	.343	268
3.4	.471	188	.438	218	.408	250	.383	284
3.6	.522	199	.485	231	.452	265	.425	301
3.8	.576	210	.535	243	.499	280	.468	318
4.0	.632	221	.587	256	.548	294	.513	335
4.2	.691	232	.641	269	.598	309	.561	352
4.4	.751	243	.698	282	.651	324	.611	368
4.6	.815	254	.757	295	.707	339	.662	385
4.8	.881	265	.818	308	.763	353	.715	402
5.0	.949	276	.881	321	.822	368	.770	419
5.2	1.020	287	.947	333	.883	383	.828	435
5.4	1.092	298	1.014	346	.947	397	.888	452
5.6	1.167	309	1.083	359	1.011	412	.949	469
5.8	1.245	321	1.155	372	1.078	427	1.011	486
6.0	1.325	332	1.229	385	1.148	442	1.076	502
7.0	1.75	387	1.630	449	1.520	515	1.430	586

LOSS OF HEAD BY FRICTION—(*Continued*).

INSIDE DIAMETER OF PIPE IN INCHES.

Velocity in Feet per Sec.	18		20		22		24	
	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.
2.0	.132	212	.119	262	.108	316	.098	377
2.2	.156	233	.140	288	.127	348	.116	414
2.4	.182	254	.164	314	.149	380	.136	452
2.6	.210	275	.189	340	.171	412	.157	490
2.8	.240	297	.216	366	.195	443	.180	528
3.0	.271	318	.245	393	.222	475	.204	565
3.2	.305	339	.275	419	.249	507	.229	603
3.4	.339	360	.306	445	.278	538	.255	641
3.6	.377	382	.339	471	.308	570	.283	678
3.8	.416	403	.374	497	.340	601	.312	716
4.0	.456	424	.410	523	.373	633	.342	754
4.2	.499	445	.449	550	.408	665	.374	791
4.4	.542	466	.488	576	.444	697	.407	829
4.6	.588	488	.529	602	.482	728	.441	867
4.8	.636	509	.572	628	.521	760	.476	905
5.0	.685	530	.617	654	.561	792	.513	942
5.2	.736	551	.662	680	.602	823	.552	980
5.4	.788	572	.710	707	.645	855	.591	1018
5.6	.843	594	.758	733	.690	887	.632	1055
5.8	.899	615	.809	759	.735	918	.674	1093
6.0	.957	636	.861	785	.782	950	.717	1131
7.0	1.270	742	1.143	916	1.040	1109	.953	1319

INSIDE DIAMETER OF PIPE IN INCHES.

Velocity in Feet per Sec.	26		28		30		36	
	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.	Loss of Head in Feet.	Cubic Feet per Min.
2.0	.091	442	.084	513	.079	589	.066	848
2.2	.108	486	.099	564	.093	648	.078	933
2.4	.126	531	.116	616	.109	707	.091	1018
2.6	.145	575	.134	667	.126	766	.104	1100
2.8	.165	619	.153	718	.144	824	.119	1188
3.0	.188	663	.174	770	.163	883	.135	1273
3.2	.211	708	.195	821	.182	942	.152	1357
3.4	.235	752	.218	872	.204	1001	.169	1442
3.6	.261	796	.242	923	.226	1060	.188	1527
3.8	.288	840	.267	974	.249	1119	.207	1612
4.0	.315	885	.293	1026	.273	1178	.228	1697
4.2	.345	929	.320	1077	.299	1237	.249	1782
4.4	.375	973	.348	1129	.325	1296	.271	1866
4.6	.407	1017	.378	1180	.353	1355	.294	1951
4.8	.440	1062	.409	1231	.381	1414	.318	2036
5.0	.474	1106	.440	1283	.411	1472	.342	2121
5.2	.510	1150	.473	1334	.441	1531	.368	2206
5.4	.546	1194	.507	1385	.473	1590	.394	2291
5.6	.583	1239	.542	1437	.506	1649	.421	2376
5.8	.622	1283	.578	1488	.540	1708	.450	2460
6.0	.662	1327	.615	1539	.574	1767	.479	2545
7.0	.879	1548	.817	1796	.762	2061	.636	2968

Example.—Have 200 feet head and 600 feet of 11-inch pipe, carrying 119 cubic feet of water per minute. To find effective head. In right-hand column under 11-inch pipe, find 119 cubic feet; opposite this will be found the coefficient of friction for this amount of water, which is 444. Multiply this by the number of hundred feet of pipe, which is 6, and you will have 2.66 feet, which is the loss of head. Therefore the effective head is 200 − 2.66 = 197.34.

CONTENTS IN CUBIC FEET, U. S. GALLONS, AND WEIGHT OF WATER PER FOOT LENGTH FOR PIPE OF VARIOUS DIAMETERS, ALSO AREA IN SQUARE FEET AND INCHES, AND CIRCUMFERENCE IN INCHES.

Diameter of Pipe in Inches.	Area in Sq. Feet or Contents in Cubic Feet per Foot of Length.	Contents in U. S. Gallons per Foot Length.	Weight of Water in One-foot Length, in Pounds.	Area in Sq. Inches.	Circumference in Inches.
1	.0055	.0408	.34	.78	3.14
2	.0218	.1632	1.36	3.14	6.28
3	.0491	.3672	3.06	7.06	9.42
4	.0873	.6528	5.44	12.56	12.56
5	.1364	1.020	8.51	19.63	15.70
6	.1963	1.469	12.25	28.27	18.85
7	.2673	1.999	16.68	38.48	21.99
8	.3491	2.611	21.79	50.26	25.13
9	.4418	3.305	27.57	63.61	28.27
10	.5454	4.08	34.04	78.54	31.41
11	.66	4.937	41.19	95.03	34.55
12	.7854	5.875	49.02	113.10	37.69
13	.9218	6.895	57.54	132.73	40.84
14	1.069	7.997	66.73	153.94	43.98
15	1.227	9.180	76.60	176.71	47.12
16	1.396	10.44	87.16	201.06	50.26
18	1.768	13.22	110.31	254.47	56.54
20	2.182	16.32	136.19	314.16	62.83
22	2.640	19.75	164.79	380.13	69.11
24	3.142	23.50	196.11	452.39	75.39
26	3.687	27.58	230.16	530.93	81.68
28	4.276	31.99	266.93	615.75	87.96
30	4.909	36.72	306.42	706.86	94.24
32	5.585	41.78	348.64	804.25	100.53
34	6.305	47.16	393.59	907.92	106.81
36	7.069	52.88	441.25	1017.9	113.09
38	7.876	58.92	491.64	1134.1	119.38
40	8.727	65.28	544.76	1256.6	125.66
42	9.621	71.97	600.59	1385.4	131.94
44	10.559	78.99	659.16	1520.5	138.23
46	11.541	86.33	720.44	1661.9	144.51
48	12.566	94.00	784.45	1809.6	150.79
50	13.635	102.00	851.18	1963.5	157.08
52	14.748	110.32	920.64	2123.7	163.36
54	15.90	118.97	992.82	2290.2	169.64
60	19.63	146.88	1225.71	2827.4	188.49
66	23.76	177.72	1483.11	3421.2	207.34
72	28.27	211.51	1765.02	4071.5	226.19

NUMBER OF GALLONS IN ROUND CISTERNS AND TANKS.

Depth in Feet.	Diameter in Feet.							
	5	6	7	8	9	10	11	12
5	735	1,060	1,440	1,875	2,380	2,925	3,550	4,237
6	881	1,270	1,728	2,250	2,855	3,510	4,260	5,084
7	1,028	1,480	2,016	2,625	3,330	4,095	4,970	5,931
8	1,175	1,690	2,304	3,000	3,805	4,680	5,680	6,778
9	1,322	1,900	2,592	3,375	4,280	5,265	6,390	7,625
10	1,469	2,110	2,880	3,750	4,755	5,850	7,100	8,472
11	1,616	2,320	3,168	4,125	5,250	6,435	7,810	9,319
12	1,762	2,530	3,456	4,500	5,705	7,020	8,520	10,166
13	1,909	2,740	3,744	4,875	6,180	7,605	9,230	11,013
14	2,056	2,950	4,032	5,250	6,655	8,190	9,940	11,860
15	2,203	3,160	4,320	5,625	7,130	8,775	10,650	12,707
16	2,356	3,370	4,608	6,000	7,605	9,360	11,360	13,554
17	2,497	3,580	4,896	6,375	8,080	9,945	12,070	14,401
18	2,644	3,790	5,184	6,750	8,535	10,530	12,780	15,248
19	2,791	4,000	5,472	7,125	9,010	11,115	13,490	16,095
20	2,938	4,210	5,760	7,500	9,490	11,700	14,200	16,942

Depth in Feet.	Diameter in Feet.							
	13	14	15	16	18	20	22	24
5	4,960	5,765	6,698	7,520	9,516	11,750	14,215	16,918
6	5,952	6,918	8,038	9,024	11,419	14,100	17,059	20,302
7	6,944	8,071	9,378	10,528	13,322	16,450	19,902	23,680
8	7,936	9,224	10,718	12,032	15,225	18,800	22,745	27,070
9	8,928	10,377	12,058	13,536	17,128	21,150	25,588	30,454
10	9,920	11,530	13,398	15,040	19,031	23,500	28,431	33,838
11	10,913	12,683	14,738	16,544	20,934	25,850	31,274	37,222
12	11,904	13,836	16,078	18.048	22,837	28,200	34,117	40,606
13	12,896	14,989	17,418	19,552	24,740	30,550	36,960	43,990
14	13,888	16,142	18,758	21,056	26,643	32,900	39,803	47,374
15	14,880	17,295	20,098	22,260	28,546	35,250	42,646	50,758
16	15,872	18,448	21,438	26,064	30,449	37,600	45,489	54,142
17	16,864	19,601	22,778	25,568	32,352	39,950	48,332	57,520
18	17,856	20,754	24,118	27,072	34,255	42,300	51,175	60,910
19	18,848	21,907	25,458	28,576	36,158	44,650	54,018	64,294
20	19,840	23,060	26,798	30,080	38,062	47,000	56,861	67,678

To find the number of gallons in a tank of unequal diameter multiply the inside bottom diameter in inches by the inside top diameter in inches, then this product by 34: point off four figures and the result will be the average number of gallons to one inch in depth of the tank.

Data Regarding Water.—Doubling the diameter of a pipe increases its capacity four times.

A gallon of water (United States standard) weighs 8.3311 pounds and contains 231 cubic inches.

A cubic foot of water contains 7½ gallons, 1728 cubic inches, and weighs 62½ pounds.

Cubic feet of water multiplied by 62.5 equals pounds avoirdupois; cubic inches of water multiplied by 0.03608 equals pounds avoirdupois.

Cubic feet multiplied by 7.48 equals United States gallons.

Cubic inches multiplied by 0.004329 equals United States gallons.

A column of water 1 inch square and 2.31 feet high weighs 1 pound.

A column of water 1 inch square and 1 foot high weighs 0.433 pound.

A column of water 33.947 feet high equals the pressure of the atmosphere at the sea-level.

Water is an almost universal solvent; consequently pure water does not occur in nature. Sea-water contains nearly every known substance in solution.

The latent heat of water is 79 thermal units. When water freezes it gives off its latent heat. The latent heat of steam is 536 thermal units. When steam condenses into water it gives off its latent heat.

Pure water consists of 2 parts hydrogen and 1 part oxygen. Chemical name, hydrogen oxide; chemical symbol, H_2O. Pure water is a colorless, odorless, tasteless, transparent liquid, and is practically incompressible. Water freezes at 32° Fahr. and boils at 212° Fahr. At its maximum density, 39.1° Fahr., it is the standard for specific gravities, and 1 cubic centimetre weighs 1 gram. Salt water boils at 224° Fahr.

$$1 \text{ U. S. gallon} = \begin{cases} \text{231 cubic inches.} \\ \text{0.13369 cubic foot.} \\ \text{8.3311 pounds of distilled water.} \\ \text{8.34 pounds in ordinary practice.} \end{cases}$$

1 cubic foot =
- 62.425 pounds at 39.1° Fahr., maximum density.
- 62.418 pounds at 32° Fahr., freezing-point.
- 62.355 pounds at 62° Fahr., standard temperature.
- 59.64 pounds at 212° Fahr., boiling-point.
- 57.5 pounds at ice.
- 7.480 U. S. gallons.

1 pound = 27.7 cubic inches.
1 cubic inch = 0.03612-pound.

Data on Pumps.—DEPTH OF SUCTION.—Theoretically a perfect pump will lift water from a depth of nearly 34 feet, corresponding to a perfect vacuum (14.7 lbs. $\times$ 2.309 = 33.95 feet); but since a perfect vacuum cannot be obtained, on account of valve leakage, air contained in the water, and the vapor of the water itself, the actual height is generally less than 30 feet. In pumping hot water, the water must flow into the pump by gravity. The following table shows the theoretical maximum depth of suction for different temperatures, leakage not considered:

Temperature, F.	Absolute Pressure of Vapor, Pounds per Sq. Inch.	Vacuum in Inches of Mercury.	Maximum Depth of Suction, Feet.	Temperature, F.	Absolute Pressure of Vapor, Pounds per Sq. Inch.	Vacuum in Inches of Mercury.	Maximum Depth of Suction, Feet.
101.4	1	27.88	31.6	183.0	8	13.63	15.5
126.2	2	25.85	29.3	188.4	9	11.59	13.2
144.7	3	23.81	27.0	193.2	10	9.55	10.9
153.3	4	21.77	24.7	197.6	11	7.51	8.5
162.5	5	19.74	22.4	201.9	12	5.48	6.2
170.3	6	17.70	20.1	205.8	13	3.44	3.9
177.0	7	15.66	17.8	209.6	14	1.40	1.6

A suction-lift pump is one that raises water only to the level of the pump spout.

A force-pump is one that raises water to the pump and also forces it to any reasonable altitude above the pump

WEIGHT OF WATER PER CUBIC FOOT AT DIFFERENT TEMPERATURES.

Temperature, Fahrenheit.	Weight, Pounds per Cubic Foot.	Temperature, Fahrenheit.	Weight, Pounds per Cubic Foot.	Temperature, Fahrenheit.	Weight, Pounds per Cubic Foot.	Temperature, Fahrenheit.	Weight, Pounds per Cubic Foot.	Temperature, Fahrenheit.	Weight, Pounds per Cubic Foot.
32°	62.42	140°	61.37	240°	59.10	350°	55.52	460°	51.26
40	62.42	150	61.18	250	58.81	360	55.16	470	50.85
50	62.41	160	60.98	260	58.52	370	54.79	480	50.44
60	62.37	170	60.77	270	58.21	380	54.41	490	50.05
70	62.31	180	60.55	280	57.90	390	54.03	500	49.61
80	62.23	190	60.32	290	57.59	400	53.64	510	49.20
90	62.13	200	60.07	300	57.26	410	53.26	520	48.78
100	62.02	210	59.82	310	56.93	420	52.86	530	48.36
110	61.69	212	59.71	320	56.58	430	52.47	540	47.94
120	61.74	220	59.64	330	56.24	440	52.07	550	47.52
130	61.56	230	59.37	340	55.88	450	51.66	560	47.10

One ft. of water column at 39.1° F. = 62.425 lbs. on the square ft.
" " " " " " " = 0.4335 lb. " " " in.
" " " " " " " = 0.0295 atmospheric pressure.
" " " " " " " = 0.8826 in. mercury column at 32° F.
" " " " " " " = 773.3 ft. of air column at 32° F. and atmospheric pressure.

One lb. pressure on sq. ft. = 0.01602 ft. water column at 39.1° F.
" " " " " in. = 2.307 " " " " 39.1° F.

One atmospheric pressure = 29.92 in. mercury column = 33 9 ft. water column.

One inch of mercury column at 32° F. = 1.133 ft. water column.

One foot of air column at 32° F. and 1 atmospheric pressure = 0.001293 ft. water column.

Useful Information Regarding Water.—The mean pressure of the atmosphere is usually estimated at 14.7 pounds per square inch, so that with a perfect vacuum it will sustain a column of mercury 29.9 inches, or a column of water 33.9 feet high.

To find the pressure in pounds per square inch of a column of water, multiply the height of the column in feet by .434. Approximately, we say that every foot elevation is equal to

½ pound pressure per square inch; this allows for ordinary friction.

To find the diameter of a pump-cylinder to move a given quantity of water per minute (100 feet of piston being the standard of speed), divide the number of gallons by 4, then extract the square root, and the product will be the diameter in inches of the pump-cylinder.

To find quantity of water elevated in one minute running at 100 feet of piston speed per minute, square the diameter of the water-cylinder in inches and multiply by 4. Example: Capacity of a 5-inch cylinder is desired. The square of the diameter (5 inches) is 25, which, multiplied by 4, gives 100, the number of gallons per minute (approximately).

To find the horse-power necessary to elevate water to a given height, multiply the total weight of the water in pounds by the height in feet, and divide the product by 33,000 (an allowance of 25 per cent should be added for water-friction, and a further allowance of 25 per cent for loss in steam-cylinder).

The area of the steam-piston, multiplied by the steam pressure, gives the total amount of pressure that can be exerted. *The area of the water-piston*, multiplied by the pressure of water per square inch, gives the resistance. *A margin* must be made between the *power* and *resistance* to *move* the pistons at the required speed—say from 20 to 40 per cent, according to speed and other conditions.

To find the capacity of a cylinder in gallons. Multiplying the area in inches by the length of stroke in inches will give the total number of cubic inches; divide this amount by 231 (which is the cubical contents of a United States gallon in inches), and product is the capacity in gallons.

To find the height in feet of a column of water corresponding with a given pressure, multiply the pressure in pounds by 2.3 feet.

The following table is arranged to show at a glance the equivalent pressure due to columns of water from 10 to 400 feet in height. Also more particularly to show the number of gallons of water delivered, and the height to which it will be projected through nozzles from ¼ inch to 2 inches in diameter.

Height of Column in Feet.	Corresponding Pressure in Pounds per Square Inch.	Diameter of Nozzle in Inches.																	
		¼		½		⅝		¾		1		1¼		1½		1¾			
		Height of Jet in Feet.	Gallons Discharged per Minute.	Height of Jet in Feet.	Gallons Discharged per Minute.	Height of Jet in Feet.	Gallons Discharged per Minute.	Height of Jet in Feet.	Gallons Discharged per Minute.	Height of Jet in Feet.	Gallons Discharged per Minute.	Height of Jet in Feet.	Gallons Discharged per Minute.	Height of Jet in Feet.	Gallons Discharged per Minute.	Height of Jet in Feet.	Gallons Discharged per Minute.	Height of Jet in Feet.	Gallons Discharged per Minute.
10	4.3	9.37	3.6	9.7	14.5	9.7	22.7	9.8	32.8	9.8	58.2	9.9	91	9.9	130.8	9.9	177.6	9.9	232.8
20	8.6	17.5	5.1	18.7	20.6	19	32.2	19.2	46.2	19.4	82.3	19.5	128.4	19.6	184.8	19.6	252	19.7	328.8
30	13.0	24.4	6.4	27.2	25.2	27.7	39.4	28.3	56.8	28.6	100.9	29	157.2	29.1	226.8	29.2	309.6	29.3	403.2
40	17.3	30.0	7.3	35.0	29.5	36	45.5	37	65.5	37.5	116.5	38	182.4	38.3	261.6	38.6	356.4	38.7	465.6
50	21.6	34.0	8.1	42.2	32.5	44	50.9	45	73.3	46.1	130.8	47	204	47.4	292.8	48	408	48	520.8
60	26	37.5	8.9	48.7	35.6	51	55.7	52	80.3	54.4	142.8	55	223.2	56.2	320.4	57	436.8	57	571.2
70	30.3	39	9.6	55	38.5	58	60.1	60	86.8	62.4	154.8	64	241.2	65	346.8	66	471.6	66	616.8
80	34.6	40	10.3	60	41.2	64	64.3	67	92.6	70	164.4	72	258	73	370.8	74	505.2	75	658.8
90	39	39.4	10.9	65	43.7	70	68.3	73	98.4	77	174.0	80	272.4	82	393.6	83	535.2	84	711.6
100	43.3	37.5	11.5	69	46.1	75	72.0	79	103.7	84	183.6	87	288	90	415.2	91	565.2	92	738
120	52	.....	.....	75	50.4	84	78.8	90	113.5	97	201.6	102	315.6	105	453.6	107	626.4	109	807.6
140	60.6	.....	.....	79	54.5	91	85.2	99	122.4	109	217.2	116	340.8	120	490.8	123	668.4	125	872.4
160	69.3	.....	.....	80	58.1	96	90.8	106	131.2	120	232.9	128	364	133	524.2	137	713.5	140	931.9
180	78	.....	.....	78.75	61.6	99	96.5	112	139.1	129	247.1	139	373.2	141	556.1	151	756.9	155	988.6
200	86.6	.....	.....	75	65.2	100	101.8	116	146.4	137	260.4	150	406.8	158	588	166	798	169	1043
220	95.1	.....	.....	.....	.....	99	106.7	119	153.7	145	273.3	159	427.1	165	615	177	837.1	182	1087.6
240	104	.....	.....	.....	.....	96	111.5	120	160.6	150	285.5	168	446.1	180	642.4	189	874.3	195	1142
260	112.6	.....	.....	.....	.....	92	116.0	119.2	167.1	155	297.1	175	464.2	190	668.5	200	909.9	208	1188.4
280	121.2	.....	.....	.....	.....	84	120.4	116.7	173.4	158	308.3	182	481.8	198	693.8	210	944.3	219	1233.4
300	130	.....	.....	.....	.....	75	124.8	112.5	178.8	160	319.2	187	498	206	717.6	220	979.2	230	1276.8
350	151.4	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	198	538.5	222	775.5	241	1055.5	255	1378.7
400	173.0	.....	.....	.....	.....	.....	.....	.....	.....	.....	.....	200	576	233	829.4	257	1128.9	275	1474.5

The pressure of head water is taken at the nozzle, no allowance being made for friction in the pipe. In practical calculations to determine the height to which water can be thrown, the head consumed by the friction of the water in flowing from the pump to the nozzle must be considered.

WEIGHT AND CAPACITY OF DIFFERENT STANDARD GALLONS OF WATER.

	Cubic Inches in a Gallon.	Weight of a Gallon in Pounds.	Gallons in a Cubic Foot.
Imperial or English...........	277.274	10.00	6.232102
United States.................	231	8.33111	7.480519

DISCHARGE OF WATER IN PIPES.

For any Length and Head, and for Diameters from 1 Inch to 10 Feet, in Cubic Feet per Minute.—(Beardmore.)

Diameter. Ft.	Ins.	Tabular Number.	Diameter. Ft.	Ins.	Tabular Number.	Diameter. Ft.	Ins.	Tabular Number.
	1	4.71	1	7	7433	3	7	57265
	1.25	8.48	1	8	8449	3	8	60648
	1.5	13.02	1	9	9544	3	9	64156
	1.75	19.15	1	10	10722	3	10	67782
	2	26.69	1	11	11983	3	11	71526
	2.5	46.67	2		13328	4		75392
	3	73.5	2	1	14758	4	3	87730
	3.5	108.14	2	2	16278	4	6	101207
	4	151.02	2	3	17889	4	9	115854
	4.5	194.84	2	4	19592	5		131703
	5	263.87	2	5	21390	5	3	148791
	6	416.54	2	6	23282	5	6	167139
	7	612.32	2	7	25270	5	9	186786
	8	654.99	2	8	27358	6		207754
	9	1147.6	2	9	29547	6	6	253781
	10	1493.5	2	10	31834	7		305437
	11	1894.9	2	11	34228	7	6	362935
1		2356	3		36725	8		426481
1	1	2876.7	3	1	39329	8	6	496275
1	2	3463.3	3	2	42040	9		572508
1	3	4115.9	3	3	44863	9	6	655369
1	4	4836.9	3	4	47794	10		745038
1	5	5628.5	3	5	50835			
1	6	6493.1	3	6	53995			

This table is applicable to sewers and drains by taking same proportion of tabular numbers that area of cross-section of water in sewer or drain bears to whole area of sewer or drain.

To Compute Volume Discharged when Length of Pipe, Height or Fall, and Diameter are Given.—*Rule.*—Divide tabular number, opposite to diameter of tube, by square root of rate of inclination, and quotient will give volume required in cubic feet per minute.

Example.—A pipe has a diameter of 9 inches, and a length of 4750 feet; what is its discharge per minute under a head of 17.5 feet?

Tab. No. 9 in. = 1147.6, and $\frac{1147.61}{\sqrt{\frac{4750}{17.5}}} = \frac{1147.61}{16.47} = 69.67$ cubic feet.

TO COMPUTE DIAMETER WHEN LENGTH, HEAD, AND VOLUME ARE GIVEN.—*Rule.*—Multiply discharge per minute by square root of ratio of inclination; take nearest corresponding number in table, and opposite to it is diameter required.

Example.—Take elements of preceding case.

$69.67 \times \sqrt{\frac{4750}{17.5}} = 1147.61$, and opposite to this is 9 inches.

Or, $\sqrt[5]{\frac{vl}{1542h}} = d$ in feet; v representing velocity in feet per second, and l length in feet.

TO COMPUTE HEAD WHEN LENGTH, DISCHARGE, AND DIAMETER ARE GIVEN.—*Rule.*—Divide tabular number for diameter by discharge per minute, square quotient, and divide length of pipe by it; quotient will give head necessary to force given volume of water through pipe in one minute.

Example.—Take elements of preceding cases:

$$\frac{1147.61}{69.67} = 16.47;\ 16.47^2 = 271.3;\ 4750 \div 271.2 = 17.5 \text{ feet.}$$

TO COMPUTE VELOCITY WHEN VOLUME AND DIAMETER ALONE ARE GIVEN.—*Rule.*—Divide volume when in feet per minute by area in feet, and quotient, divided by 60, will give velocity in feet per second.

Example.—Take elements of preceding case:

$$\frac{69.67}{0.75^2 \times 0.7854} \div 60 = 2.63 \text{ feet.}$$

WHEN VOLUME IS NOT GIVEN —*Rule.*—Multiply square root of product of height of pipe by diameter in feet, divided by length in feet, by 50, and product will give velocity in feet per second. (Beardmore.)

TO COMPUTE INCLINATION OF PIPE WHEN VOLUME, DIAMETER, AND LENGTH ARE GIVEN: $\left\{\frac{V}{2356}\right\}^2 \frac{1}{D^5} = \frac{H}{L}$.

Illustration.—Take elements of preceding case:

$$\left\{\frac{69.67}{2356}\right\}^2 \times \frac{1}{0.75^5} = 0.000847 \times 4.214 = 0.00368,$$

and

$$\frac{17.5}{4750} = 0.00368, \quad \text{or} \quad 4750 \times 0.00368 = 17.49 \text{ ft. head.}$$

EQUATION OF PIPES.

It is frequently desired to know what number of pipes of a given size are equal in carrying capacity to one pipe of a larger size. At the same velocity of flow the volume delivered by two pipes of different sizes is proportional to the squares of their diameters; thus, one 4-inch pipe will deliver the same volume as four 2-inch pipes. With the same head, however, the velocity is less in the smaller pipe, and the volume delivered varies about as the square root of the fifth power (i.e., as the 2.5 power). The following table has been calculated on this basis. The figures opposite the intersection of any two sizes represent the number of the smaller-sized pipes required to equal one of the larger. Thus, one 4-inch pipe is equal to 5.7 2-inch pipes.

Diameter, Inches.	1	2	3	4	5	6	7	8	9	10	12	14	16	18	20	24
2	5.7	1														
3	15.6	2.8	1													
4	32	5.7	2.1	1												
5	55.9	9.9	3.6	1.7	1											
6	88.2	15.6	5.7	2.8	1.6	1										
7	130	22.9	8.3	4.1	2.3	1.5	1									
8	181	32	11.7	5.7	3.2	2.1	1.4	1								
9	243	43	15.6	7.6	4.3	2.8	1.9	1.3	1							
10	316	55.9	20.3	9.9	5.7	3.6	2.4	1.7	1.3	1						
11	401	70.9	25.7	12.5	7.2	4.6	3.1	2.2	1.7	1.3						
12	499	88.2	32	15.6	8.9	5.7	3.8	2.8	2.1	1.6	1					
13	609	108	39.1	19	10.9	7.1	4.7	3.4	2.5	1.9	1.2					
14	733	130	47	22.9	13.1	8.3	5.7	4.1	3.0	2.3	1.5	1				
15	787	154	55.9	27.2	15.6	9.9	6.7	4.8	3.6	2.8	1.7	1.2				
16	......	181	65.7	32	18.3	11.7	7.9	5.7	4.2	3.2	2.1	1.4	1			
17	......	211	76.4	37.2	21.3	13.5	9.2	6.6	4.9	3.8	2.4	1.6	1.2			
18	......	243	88.2	43	24.6	15.6	10.6	7.6	5.7	4.3	2.8	1.9	1.3	1		
19	......	278	101	49.1	28.1	17.8	12.1	8.7	6.5	5	3.2	2.1	1.5	1.1		
20	......	316	115	55.9	32	20.3	13.8	9.9	7.4	5.7	3.6	2.4	1.7	1.3	1	
22	......	401	146	70.9	40.6	25.7	17.5	12.5	9.3	7.2	4.6	3.1	2.2	1.7	1.3	
24	......	499	181	88.2	50.5	32	21.8	15.6	11.6	8.9	5.7	3.8	2.8	2.1	1.6	1
26	......	609	221	108	61.7	39.1	26.6	19	14.2	10.9	7.1	4.7	3.4	2.5	1.9	1.2
28	......	733	266	130	74.2	47	32	22.9	17.1	13.1	8.3	5.7	4.1	3	2.3	1.5
30	......	787	316	154	88.2	55.9	38	27.2	20.3	15.6	9.9	6.7	4.8	3.6	2.8	1.7
36	......	......	499	243	130	88.2	60	43	32	24.6	15.6	10.6	7.6	5.7	4.3	2.8
42	......	......	733	357	205	130	88.2	63.2	47	36.2	19	15.6	11.2	8.3	6.4	4.1
48	......	......	......	499	286	181	123	88.2	62.7	50.5	32	21.8	15.6	11.6	8.9	5.7
54	......	......	......	670	383	243	165	118	88.2	67.8	43	29.2	20.9	15.6	12	7.6
60	......	......	......	787	499	316	215	154	115	88.2	55.9	38	27.2	20.3	15.6	9.9

TABLES OF WEIGHTS, STRENGTHS, ETC.

SPECIFIC GRAVITY OF VARIOUS SUBSTANCES.

Names of Substances.	Specific Gravity.
Aluminum cast	2.60
hammered	2.75
Amber	1.08
Anthracite	1.40-1.70
Asphaltum	1.10-1.20
Brass cast	8.40-8.70
rolled	8.57
Brick, common, hard	1.53-2.30
Cement, ground, loose	1.85
Charcoal	0.44
Cherry, dry	0.76-0.84
Clay, dry	1.80-2.60
Coal, bituminous	1.20-1.50
Coke, loose	0.55
Concrete	2.47
Copper cast	8.79
rolled	8.78-9.00
Diamond	3.52
Earth, humus	1.30-1.80
Glass, common window	2.64
Gneiss, common	2.40-2.70
Gold cast, pure, or 24 carat	19.28
pure, hammered	19.33
Granite	2.50-3.00
Gypsum, cast, dry	0.97
Hornblende	3.00
Ice	0.88-0.92
Iron cast	7.10-7.50
wrought	7.79
Ivory	1.82
Lead	11.37
Lime	2.30-3.20
Lime, slaked	1.30-1.40
Limestones	2.46-2.84
Magnesium	1.74

Names of Substances.	Specific Gravity.
Mahogany	0.56-1.09
Maple, dry	0.70
Marble	2.52-2.85
Masonry, stone, dry	2.00-2.55
" brick, "	1.50-1.60
Mercury at 32° Fahr.	13.596
Mica	2.80
Nickel	8.8
Oak, dry	0.69-1.03
Petroleum at 59° Fahr.	0.80
Pine	0.35-0.60
Platinum cast	21.15
hammered	21.3-21.5
Quartz	2.5-2.80
Saltpetre, Chili	2.26
" Kali	1.95-2.08
Sand, fine, dry	1.40-1.65
" wet	1.90-2.05
" coarse	1.40-1.50
Sandstone	2.20-2.50
Silver cast	10.48
hammered	10.62
Slate	2.60-2.70
Snow, freshly fallen	0.19
Steel	7.26-7.86
Sulphur	1.93-2.07
Sodium	0.978
Tin cast	7.20
rolled	7.30
Water, pure rain or distilled, at 39° F	1.00
Water, sea	1.03
Walnut, dry	0.60-0.81
Wax	0.95-0.98
Zinc cast	6.90
rolled	7.20

WEIGHT OF A CUBIC FOOT OF SUBSTANCES.

Names of Substances.	Average Weight, Pounds.
Aluminum	162
Anthracite, solid, of Pennsylvania	93
" broken, loose	54
" " moderately shaken	58
" heaped bushel, loose	(80)
Ash, American, white, dry	38
Asphaltum	87

WEIGHT OF SUBSTANCES—(*Continued*).

Names of Substances.	Average Weight, Pounds.
Brass (copper and zinc), cast	504
" rolled	524
Brick, best pressed	150
" common, hard	125
" soft, inferior	100
Brickwork, pressed brick	140
" ordinary	112
Cement, hydraulic, ground, loose, American Rosendale	56
" " " " " Louisville	50
" " " " English, Portland	90
Cherry, dry	42
Chestnut, dry	41
Clay, potters' dry	119
" in lump, loose	63
Coal, bituminous, solid	84
" " broken, loose	49
" " heaped bushel, loose	(74)
Coke, loose, of good coal	26.3
" " heaped bushel	(40)
Copper, cast	542
" rolled	548
Earth, common loam, dry, loose	76
" " " " moderately rammed	95
" as a soft, flowing mud	108
Ebony, dry	76
Elm, dry	35
Flint	162
Glass, common window	157
Gneiss, common	168
Gold, cast, pure, or 24 carat	1204
" pure, hammered	1217
Grain, at 60 lbs. per bushel	48
Granite	170
Gravel, about the same as sand, which see.	
Gypsum (plaster of Paris)	142
Hemlock, dry	25
Hickory, dry	53
Hornblende, black	203
Ice	58.7

WEIGHT OF SUBSTANCES—(*Continued*).

Names of Substances.	Average Weight, Pounds.
Iron, cast	450
" wrought, purest	485
" " average	480
Ivory	114
Lead	711
Lignum vitæ, dry	83
Lime, quick, ground, loose, or in small lumps	53
" " " " thoroughly shaken	75
" " " " per struck bushel	66
Limestones and marbles	168
" " " loose, in irregular fragments	96
Magnesium	109
Mahogany, Spanish, dry	53
" Honduras, dry	35
Maple, dry	45
Marbles, see Limestones.	
Masonry, of granite or limestone, well dressed	165
" " mortar rubble	154
" " dry " (well scabbled)	138
" " sandstone, well dressed	144
Mercury, at 32° Fahrenheit	849
Mica	183
Mortar, hardened	103
Mud, dry, close	80 to 110
Mud, wet, fluid, maximum	120
Oak, live, dry	59
Oak, white, dry	50
" other kinds	32 to 45
Petroleum	55
Pine, white, dry	25
" yellow, Northern	34
" " Southern	45
Platinum	1342
Quartz, common, pure	165
Rosin	69
Salt, coarse, Syracuse, N. Y.	45
" Liverpool, fine, for table use	49
Sand, of pure quartz, dry, loose	90 to 106
" well shaken	99 to 117

WEIGHT OF SUBSTANCES—(*Continued*).

Names of Substances.	Average Weight, Pounds.
Sand, perfectly wet	120 to 140
Sandstones, fit for building	151
Shales, red or black	162
Silver	655
Slate	175
Snow, freshly fallen	5 to 12
" moistened and compacted by rain	15 to 50
Spruce, dry	25
Steel	490
Sulphur	125
Sycamore, dry	37
Tar	62
Tin, cast	459
Turf or peat, dry, unpressed	20 to 30
Walnut, black, dry	38
Water, pure rain or distilled, at 60° Fahrenheit	$62\frac{1}{3}$
" sea	64
Wax, bees	60.5
Zinc or spelter	437.5

Green timbers usually weigh from one-fifth to one-half more than dry.

WEIGHT OF DIFFERENT MATERIALS.

	Pounds.
1 barrel of lime	200 to 230
1 " " cement (hydraulic or Rosendale)	300
1 " " " (Portland)	400
1 " " " (Scotch, Roman)	350
1 " " fire-clay (American)	300
1 " " " (English)	350
1 " " brick-dust	350
1 " " marble-dust	350
1 " " plaster, California	260
1 " " " Wotherspoon (Eastern)	275
1 " " " (ground gypsum or land)	320

Fire-brick $6\frac{1}{2}$ to 7 pounds each.

LINEAR EXPANSION OF SUBSTANCES BY HEAT.

To find the increase in the length of a bar of any material due to an increase of temperature, multiply the number of degrees of increase of temperature by the coefficient for 100 degrees and by the length of the bar and divide by 100.

Name of Substance.	Coefficient for 100° Fahrenheit.	Coefficient for 180° Fahrenheit, or 100° Centigrade.
Baywood (in the direction of the grain, dry)	.00026 to .00031	.00046 to .00057
Brass (cast)	.00104	.00188
" (wire)	.00107	.00193
Brick (fire)	.0003	.0005
Cement (Roman)	.0008	.0014
Copper	.0009	.0017
Deal (in the direction of the grain, dry)	.00024	.00044
Glass (English flint)	.00045	.00081
" (French white lead)	.00048	.00087
Gold	.0008	.0015
Granite (average)	.00047	.00085
Iron (cast)	.0006	.0011
" (soft forged)	.0007	.0012
" (wire)	.0008	.0014
Lead	.0016	.0029
Marble (Carrara)	.00036 to .0006	.00065 to .0011
Mercury	.0033	.0060
Platinum	.0005	.0009
Sandstone	.0005 to .0007	.0009 to .0012
Silver	.0011	.002
Slate (Wales)	.0006	.001
Water (varies considerably with the temperature)	.0086	.0155
Tin	.0003	.0069
Zinc	.0004	.0088

STRENGTH OF MATERIALS.

Ultimate resistance to tension, in pounds per square inch.

METALS AND ALLOYS.

Aluminum bronze:	Average.
10 per cent Al and 90 per cent copper	85,000
1¼ " " " 98½ " "	28,000
Brass, cast	18,000
Brass wire	49,000
Bronze or gun metal	36,000
Copper, cast	19,000
Copper, sheet	30,000
Copper, bolts	36,000
Copper wire (unannealed)	60,000
Iron, cast, 13,400 to 29,000	16,500
Iron wire, black or annealed	56,000
Iron wire, bright, hard drawn	78,400
Lead, sheet	3,300
Steel	45,000 to 120,000
Steel aluminum, 2½ per cent aluminum	70,000
Steel copper, 35 per cent copper	60,000
Steel nickel, 3¼ per cent nickel	86,000
Steel cast, wire Bessemer	2,896,000
Steel cast, wire high carbon	179,200
Steel cast, wire mild O. H	134,000

The modulus of elasticity of steel from recent tests is from 27,000,000 to 31,000,000. Average, 29,000,000.

Tin, cast	4,600
Zinc	7,000 to 8,000

STONE, NATURAL AND ARTIFICIAL.

Brick and cement	280 to 300
Glass	2,560
Slate	2,400 to 4,600
Mortar, ordinary lime	10 to 20

ULTIMATE RESISTANCE TO COMPRESSION.

Metals.

Brass, cast	10,300
Iron, "	85,000 to 125,000
Steel	45,000 to 120,000

STONE, NATURAL AND ARTIFICIAL.

	Average.
Brick, weak	550 to 800
" strong	1,100
" fire	1,700
Brickwork, ordinary, in cement	300 to 600
" best	1,000
Glass	30,000
Granite	5,000 to 18,000
Limestone	4,000 to 16,000
Marble	4,000 to 18,000
Sandstone, ordinary	2,500 to 10,000

ULTIMATE RESISTANCE TO SHEARING.

Metals.

Iron, cast	25,000
Steel	50,000

MODULI OF ELASTICITY.

Metals.

Iron (cast)	12,000,000
Iron (wrought shapes)	27,000,000
Iron (rerolled bars)	26,000,000
Steel (casting)	30,000,000
Steel (structural)	29,000,000

WEIGHT, STRENGTH, ETC., OF STANDARD HOISTING ROPE

Composed of Six Strands and a Hemp Centre, Nineteen Wires to the Strand

Swedish Iron.

Trade Number.	Diameter in Inches.	Approximate Circumference in Inches.	Weight per Foot in Pounds.	Approximate Breaking Strain in Tons of 2000 Pounds.	Allowable Working Strain in Tons of 2000 Pounds.	Minimum Size of Drum or Sheave in Feet.
..	$2\frac{3}{4}$	$8\frac{5}{8}$	11.95	114	22.8	16
..	$2\frac{1}{2}$	$7\frac{7}{8}$	9.85	95	18.9	15
1	$2\frac{1}{4}$	$7\frac{1}{8}$	8.00	78	15.60	13
2	2	$6\frac{1}{4}$	6.30	62	12.40	12
3	$1\frac{3}{4}$	$5\frac{1}{2}$	4.85	48	9.60	10
4	$1\frac{5}{8}$	5	4.15	42	8.40	$8\frac{1}{2}$
5	$1\frac{1}{2}$	$4\frac{3}{4}$	3.55	36	7.20	$7\frac{1}{2}$
$5\frac{1}{2}$	$1\frac{3}{8}$	$4\frac{1}{4}$	3.00	31	6.20	7
6	$1\frac{1}{4}$	4	2.45	25	5.00	$6\frac{1}{2}$
7	$1\frac{1}{8}$	$3\frac{1}{2}$	2.00	21	4.20	6
8	1	3	1.58	17	3.40	$5\frac{1}{4}$
9	$\frac{7}{8}$	$2\frac{3}{4}$	1.20	13	2.60	$4\frac{1}{2}$
10	$\frac{3}{4}$	$2\frac{1}{4}$	0.89	9.7	1.94	4
$10\frac{1}{4}$	$\frac{5}{8}$	2	0.62	6.8	1.36	$3\frac{1}{2}$
$10\frac{1}{2}$	$\frac{9}{16}$	$1\frac{3}{4}$	0.50	5.5	1.10	$2\frac{3}{4}$
$10\frac{3}{4}$	$\frac{1}{2}$	$1\frac{1}{2}$	0.39	4.4	0.88	$2\frac{1}{4}$
10*a*	$\frac{7}{16}$	$1\frac{1}{4}$	0.30	3.4	0.68	2
10*b*	$\frac{3}{8}$	$1\frac{1}{8}$	0.22	2.5	0.50	$1\frac{1}{2}$
10*c*	$\frac{5}{16}$	1	0.15	1.7	0.34	1
10*d*	$\frac{1}{4}$	$\frac{3}{4}$	0.10	1.2	0.24	$\frac{3}{4}$

Cast Steel.

Trade Number.	Diameter in Inches.	Approximate Circumference in Inches.	Weight per Foot in Pounds.	Approximate Breaking Strain in Tons of 2000 Pounds.	Allowable Working Strain in Tons of 2000 Pounds.	Minimum Size of Drum or Sheave in Feet.
..	$2\frac{3}{4}$	$8\frac{5}{8}$	11.95	228	45.6	10
..	$2\frac{1}{2}$	$7\frac{7}{8}$	9.85	190	37.9	$9\frac{1}{2}$
1	$2\frac{1}{4}$	$7\frac{1}{8}$	8.00	156	31.2	$8\frac{1}{2}$
2	2	$6\frac{1}{4}$	6.30	124	24.8	8
3	$1\frac{3}{4}$	$5\frac{1}{2}$	4.85	96	19.2	$7\frac{1}{4}$
4	$1\frac{5}{8}$	5	4.15	84	16.8	$6\frac{1}{4}$
5	$1\frac{1}{2}$	$4\frac{3}{4}$	3.55	72	14.4	$5\frac{3}{4}$
$5\frac{1}{2}$	$1\frac{3}{8}$	$4\frac{1}{4}$	3.00	62	12.4	$5\frac{1}{2}$
6	$1\frac{1}{4}$	4	2.45	50	10.0	5
7	$1\frac{1}{8}$	$3\frac{1}{2}$	2.00	42	8.40	$4\frac{1}{2}$
8	1	3	1.58	34	6.80	4
9	$\frac{7}{8}$	$2\frac{3}{4}$	1.20	26	5.20	$3\frac{1}{2}$
10	$\frac{3}{4}$	$2\frac{1}{4}$	0.89	19.4	3.88	3
$10\frac{1}{4}$	$\frac{5}{8}$	2	0.62	13.6	2.72	$2\frac{1}{4}$
$10\frac{1}{2}$	$\frac{9}{16}$	$1\frac{3}{4}$	0.50	11.0	2.20	$1\frac{3}{4}$
$10\frac{3}{4}$	$\frac{1}{2}$	$1\frac{1}{2}$	0.39	8.8	1.76	$1\frac{1}{2}$
10*a*	$\frac{7}{16}$	$1\frac{1}{4}$	0.30	6.8	1.36	$1\frac{1}{4}$
10*b*	$\frac{3}{8}$	$1\frac{1}{8}$	0.22	5.0	1.00	1
10*c*	$\frac{5}{16}$	1	0.15	3.4	0.68	$\frac{3}{4}$
10*d*	$\frac{1}{4}$	$\frac{3}{4}$	0.10	2.4	0.48	$\frac{1}{2}$

WEIGHT, STRENGTH, ETC., OF EXTRA STRONG CRUCIBLE CAST-STEEL ROPE.

Composed of Six Strands and a Hemp Centre, Nineteen Wires to the Strand.

Trade Number.	Diameter in Inches.	Approximate Circumference in Inches.	Weight per Foot in Pounds.	Approximate Breaking Strain in Tons of 2000 Pounds.	Allowable Working Strain in Tons of 2000 Pounds.	Minimum Size of Drum or Sheave in Feet.
..	2¾	8⅝	11.95	266	53	10
..	2½	7⅞	9.85	222	45	9½
1	2¼	7⅛	8.00	182	36.4	8½
2	2	6¼	6.30	144	28.8	8
3	1¾	5½	4.85	112	22.4	7¼
4	1⅝	5	4.15	97	19.4	6¼
5	1½	4¾	3.55	84	16.8	5¾
5½	1⅜	4¼	3.00	72	14.4	5½
6	1¼	4	2.45	58	11.6	5
7	1⅛	3½	2.00	49	9.80	4½
8	1	3	1.58	39	7.80	4
9	⅞	2¾	1.20	30	6.00	3½
10	¾	2¼	0.89	22	4.40	3
10¼	⅝	2	0.62	15.8	3.16	2¼
10½	$\frac{9}{16}$	1¾	0.50	12.7	2.54	1¾
10¾	½	1½	0.39	10.1	2.02	1½
10*a*	$\frac{7}{16}$	1¼	0.30	7.8	1.56	1¼
10*b*	⅜	1⅛	0.22	5.78	1.15	1
10*c*	$\frac{5}{16}$	1	0.15	4.05	0.81	¾
10*d*	¼	¾	0.10	2.70	0.54	½

Seven Wires to the Strand.

11	1½	4¾	3.55	79	15.8	8½
12	1⅜	4¼	3.00	68	13.6	8
13	1¼	4	2.45	56	11.2	7¼
14	1⅛	3½	2.00	46	9.20	6¼
15	1	3	1.58	37	7.40	5¾
16	⅞	2¾	1.20	28	5.60	5
17	¾	2¼	0.89	21	4.20	4½
18	$\frac{11}{16}$	2⅛	0.75	18.4	3.68	4
19	⅝	2	0.62	15.1	3.02	3½
20	$\frac{9}{16}$	1¾	0.50	12.3	2.46	3
21	½	1½	0.39	9.70	1.94	2½
22	$\frac{7}{16}$	1¼	0.30	7.50	1.50	2¼
23	⅜	1⅛	0.22	5.58	1.11	2
24	$\frac{5}{16}$	1	0.15	3.88	0.77	1¾
25	$\frac{9}{32}$	⅞	0.125	3.22	0.64	1½

WEIGHT, STRENGTH, ETC., OF COPPER, IRON, TINNED AND GALVANIZED SASH-CORDS.

Composed of Six Strands and a Cotton Centre, Seven Wires to the Strand.

Trade Number.	Diameter in Inches.	Weight per Foot in Pounds.		Approximate Breaking Strain in Pounds.		
		Iron.	Copper.	Iron.		Bright Copper.
				Bright.	Annealed.	
26	1/4	0.100	0.115	2200	1600	1265
27	7/32	0.076	0.087	1809	1254	1022
27 1/2	3/16	0.056	0.064	1417	947	792
28	1/8	0.025	0.029	790	467	435
28 1/2	3/32	0.014	0.016	510	280	272
29	1/16	0.006	0.007	262	132	140

APPROXIMATE WEIGHT AND STRENGTH OF MANILA ROPE.

Manila, Sisal, New Zealand, and Jute Ropes weigh (about) alike. Tarred Hemp Cordage will weigh (about) one-fourth more. Manila is about 25 per cent stronger than Sisal. Working load about one-fourth of breaking strain.

Circumference in Inches.	Diameter in Inches.	Weight of 1000 Feet in Pounds.	Number of Feet and Inches in One Pound.		Strength of New Manila Rope in Pounds.
			Ft.	Ins.	
3/4	1/4	23	50		450
1	5/16	33	33		780
1 1/8	3/8	42	25		1,000
1 1/4	7/16	52	19		1,280
1 1/2	1/2	74	11		1,760
1 3/4	9/16	101	9		2,400
2	5/8	132	7		3,140
2 1/4	3/4	167	6		3,970
2 1/2	13/16	207	5		4,900
2 3/4	7/8	250	4		5,900
3	1	297	3	6	7,000
3 1/4	1 1/16	349	2	10	8,200
3 1/2	1 1/8	405	2	4	9,600
3 3/4	1 1/4	465	2	1	11,000
4	1 5/16	529	1	10	12,500
4 1/4	1 3/8	597	1	8	14,000
4 1/2	1 7/16	669	1	5	15,800
4 3/4	1 1/2	746	1.	4	17,600
5	1 5/8	826	1	2	19,500
5 1/2	1 3/4	1000	1		23,700
6	1 7/8	1190		10	28,000
6 1/4	2	1291		9 1/2	33,000
6 1/2	2 1/8	1397		8 1/2	38,000
7	2 1/4	1620		7	44,000
7 1/2	2 3/8	1860		6 1/2	50,000
8	2 9/16	2116		5 1/2	60,000
8 1/2	2 3/4	2388		5	63,000
9	2 7/8	2673		4 1/2	67,700
9 1/2	3	2983		4	70,000
10	3 3/16	3306		3 5/8	78,000

WIRE ROPE FOR INCLINE PLANES.

For inclines and other places where wire cables are subject to friction, coarse wires are preferable to fine, since the latter wear in two more rapidly.

This table gives only the strain produced on a rope by a load of one ton of 2000 pounds, an allowance for rolling friction being made. An additional allowance for the weight of the rope will have to be made.

Example.—For an inclination of 100 feet in 100 feet, corresponding to an angle of 45°, a load of 2000 pounds will produce a strain on the rope of 1419 pounds, and for a load of 9000 pounds the strain on the rope will be $(1419 \times 9000) \div 200 = 6{,}385\frac{1}{2}$ pounds, or $3\frac{385}{2000}$ tons.

Elevation in 100 Feet.	Corresponding Angle in Degrees of Inclination.	Strain in Pounds on Rope from a Load of 2000 Pounds.	Elevation in 100 Feet.	Corresponding Angle in Degrees of Inclination.	Strain in Pounds on Rope from a Load of 2000 Pounds.
5	2⅞	112	70	35	1156
10	5½	211	75	37	1210
15	8⅓	308	80	38⅔	1260
20	11⅛	404	85	40½	1304
25	14½	497	90	42	1347
30	16¾	586	95	43½	1385
35	19⅛	673	100	45	1419
40	21⅝	754	105	46½	1457
45	24¼	832	110	47¾	1487
50	26⅓	905	115	49	1516
55	28⅚	975	120	50¼	1544
60	31	1040	125	51½	1570
65	33 1/12	1100			

A factor of safety of five to seven times should be taken; that is, the working load on the rope should only be one-fifth to one-seventh of its breaking strength. As a rule, ropes for shafts should have a factor of safety of five, and on inclined planes, where the wear is much greater, the factor of safety should be sveen.

TABLE SHOWING HOW THE LIFE OF AN INCLINE STEEL-WIRE ROPE IS AFFECTED BY REDUCING THE SIZE OF SHEAVES AND DRUMS.

Computed for Ropes of Seven Wires to the Strand.

Diameter of Rope in Ins.	Diameter of Sheaves or Drums in Feet, showing Percentages of Life for Various Diameters.						
	100 Per Cent.	90 Per Cent.	80 Per Cent.	75 Per Cent.	60 Per Cent.	50 Per Cent.	25 Per Cent.
	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.	Feet.
1½	16	14	12	11	9	7	4.75
1⅜	14	12	10	8.5	7	6	4.5
1¼	12	10	8	7.25	6.5	5 5	4.25
1⅛	10	8.5	7.75	7	6	5	4
1	8.5	7.75	6.75	6	5	4.5	3.75
⅞	7.75	7	6.25	5.75	4.5	3.75	3.25
¾	7	6.25	5.5	5	4.25	3.5	2.75
⅝	6	5.25	4.5	4	3.26	3	2.5
½	5	4.5	4	3.5	2.75	2.25	1.75

General Information Relating to Wire Rope.—Wire rope is made of wires either twisted together or laid parallel to each other. The latter kind is only employed on large suspension bridges, while the former is in general use.

There are two classes of twisted, or, as it is usually called, *stranded wire rope—flat and round.*

Flat wire ropes consist of a number of wire strands which have been laid side by side and sewed together with annealed wire.

Round wire ropes are composed of a number of wire strands twisted around a core of hemp or around a wire strand or wire rope.

The *standard wire rope* is made of six wire strands and a hemp core. This arrangement affords the most convenient and compact form, as the strands and the core are practically all of the same size. For special purposes, however, four, five, seven, eight, nine, or any reasonable number of strands may be utilized.

Wire strands are twisted around the core, either to the right or left, and the resulting rope is thereby designated as *right lay* or *left lay* The twist may be long or short, according to requirements. The shorter twist forms the more flexible rope, the longer twist the more rigid rope.

The *core* of a wire rope is, as a rule, hemp saturated with tar. It provides little additional strength, but acts as a cushion to preserve the shape of the rope and helps to lubricate the wires.

When the core is a *wire strand* or *rope,* it adds from 7 to 10 per cent to the strength of the rope, but will wear from the friction between it and the outer strands as rapidly as the outside of the rope. This does not apply to stationary ropes.

Wire strands are made of wires twisted together. The number of wires commonly used are four, seven, twelve, nineteen, and thirty-seven, and depends upon the nature of the work for which the strands are intended. Ordinarily the wires are twisted into strands in the *opposite direction* to the twist of the strands into rope.

When wires and strands are twisted in the *same direction,* the rope is known as "Lang" *rope.* For great flexibility, the strands of a wire rope sometimes consist of wire ropes, which in turn are made of strands composed of wires, as in tiller ropes.

When considerable outside friction and corrosion are to be resisted and pliability is also demanded, strands are made of twelve or eighteen wires, twisted about a hemp centre, as in ships' hawsers and running ropes.

Individual strands of wires are employed as smoke-stack guys, span wires for trolley roads, and wherever only moderate flexibility is needed.

Iron, open-hearth steel, crucible steel, and plough steel possess qualities which cover almost every demand upon the material of a wire rope. Copper, bronze, etc., are, however, used for a few special purposes.

In order to provide a protection against the action of salt air, rust, etc., wire is often galvanized or tinned, as for ships' rigging, etc. Ropes subject to constant bending around drums and sheaves are not usually so treated.

The *strength* of wire ropes depends primarily upon the material of which the wires are made. It is hard to obtain from a sample of wire rope more than 90 per cent of the aggregate strength of all of its wires in a testing-machine, the average being about 82½ per cent. This is due to the difficulty in making perfect attachments to the ends of the test-piece, in order that every wire shall carry its share of the load; to the fact that the inside wires of the strands are shorter than the outside wires and tend to break before them, and to the construction of the rope, which causes the adjacent strands to nick each other. While the last-mentioned action reduces the breaking strain of a rope, it occurs only at stresses far above those employed in practice. On account of the nicking, ropes with a short twist, or ropes made of hard steel break at a lower percentage of the aggregate strength of their wires than ropes with a long twist or ropes made of soft wire. So that, while it may be advisable in certain cases to use a rope with a short twist, its breaking strain will be lower than if the twist were long.

The *strength of iron wire* ranges from 45,000 to 100,000 pounds per square inch; *open-hearth steel* from 50,000 to 130,000 pounds per square inch; *crucible steel* from 130,000 to 190,000 pounds per square inch; and *plough steel* from 190,000 to 350,000 pounds per square inch, according to quality, treatment, size of wire, etc.

The *breaking strains* given in the preceding tables were determined by means of our own testing-machine, which has a capacity of 300,000 pounds, and those at Watertown Arsenal and Phœnixville. They represent fair averages of the rope usually supplied.

The *working loads* were calculated at *one-fifth* the *breaking strains*, but it should be understood that this factor of safety

is not recommended for all cases, as it is imperative to determine for every set of conditions a reasonable factor of safety. For instance, elevator ropes seldom have a load of more than one-tenth or one-fifteenth of their breaking strain.

The *minimum sizes of drums or sheaves* given in the tables were calculated on a basis of a working load of one-fifth the breaking strain, and provide that ropes shall not have their wires strained beyond the elastic limit when passing around the drums or sheaves indicated. While the theoretical sizes for cast-steel ropes are smaller than for the corresponding iron ropes, because the elastic limit of the former is much higher than of the latter, and the modulus of elasticity is nearly the same for both, still it is better to use the larger sizes of drums and sheaves for steel ropes, because when steel wire becomes worn or nicked it cracks very easily.

When high speeds are used, much larger drums and sheaves must be employed.

When working loads less than those given in the tables are used, or when the bending around sheaves and drums is very occasional, slightly smaller dimensions may be adopted.

In general, however, the *larger* the drum or sheave, the *longer* the rope will last, and the use of diameters less than those stated in the tables will often result in a rapid deterioration of the rope.

Wire rope should be *protected* from all unnecessary wear, and should be *lubricated* and kept as *dry* as possible. Wear increases with speed; it is therefore better to increase the load, within certain limits, than the speed.

For *lubrication* and to *prevent rusting*, linseed-oil, tar, or other similar materials free from acids or corrosive substances should be used. This is of the utmost importance, and is a large factor in the life of a wire rope. Applications of lubricants should be frequent, and in most cases the spaces between the strands of a wire rope should be gradually so filled that the rope eventually presents the appearance of a round iron bar. Many operators prefer to apply compositions of their own when the rope is put on, and for this reason we usually apply a coating of oil or paint merely to prevent the rope rusting while in transit or storage We, however, are prepared upon request not only to apply any of the many commercial rope coatings and preservers, but if notified in time can lay the rope up in the same, thus insuring a thorough protection and lubrication.

Wire rope must not be coiled or uncoiled like hemp rope. When it is received upon a reel, the latter should be mounted upon a spindle or turntable and the rope then run off.

When shipped in a coil, it should be rolled along the ground like a wheel. *All untwisting and kinking* must be avoided. When a wire rope is to be cut, soft iron wire should be served on each side of the place where the division is to be made to prevent the rope from untwisting.

The Right and Wrong Ways to Measure Wire Rope.—The diameter of a wire rope is that of a true circle. Note where the dotted line touches the strands in Fig. 355.

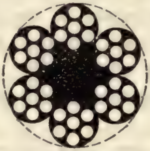


Fig. 355.

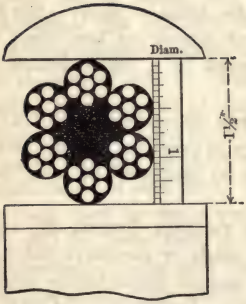


Fig. 356.
Right way to measure.
(A true circle.)

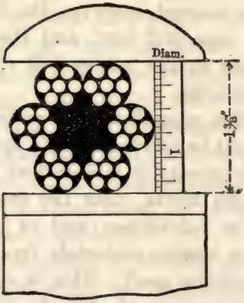


Fig. 357.
Wrong way to measure.
(Not a true circle.)

We always understand the diameter of a wire rope to be that of a circle inclosing the rope. Care should be taken in measuring to obtain this diameter. If a rope is measured the wrong way (see cut) and a wheel is ordered grooved to take the rope, the groove would be too small.

WEIGHT, LENGTH, AND STRENGTH OF STEEL WIRE.

Number, Roebling Gauge.	Diameter in Inches.	Area in Square Inches.	Breaking Strain at Rate of 100,000 Pounds per Square Inch.	Weight in Pounds.		Number of Feet in 2000 Pounds.
				Per 1000 Feet.	Per Mile.	
000000	.460	.166191	16,619	558.4	2948	3,582
00000	.430	.145221	14,522	487.9	2576	4,099
0000	.393	.121304	12,130	407.6	2152	4,907
000	.362	.102922	10,292	345.8	1826	5,783
00	.331	.086049	8,605	289.1	1527	6,917
0	.307	.074023	7,402	248.7	1313	8,041
1	.283	.062902	6,290	211.4	1116	9,463
2	.263	.054325	5,433	182.5	964	10,957
3	.244	.046760	4,676	157.1	830	12,730
4	.225	.039761	3,976	133.6	705	14,970
5	.207	.033654	3,365	113.1	597	17,687
6	.192	.028953	2,895	97.3	514	20,559
7	.177	.024606	2,461	82.7	437	24,191
8	.162	.020612	2,061	69.3	366	28,878
9	.148	017203	1,720	57.8	305	34,600
10	.135	.014314	1,431	48.1	254	41,584
11	.120	.011310	1,131	38.0	201	52,631
12	.105	.008659	866	29.1	154	68,752
13	.092	.006648	665	22.3	118	89,525
14	.080	.005027	503	16.9	89.2	118,413
15	.072	.004071	407	13.7	72.2	146,198
16	.063	.003117	312	10.5	55.3	191,022
17	.054	.002290	229	7.70	40.6	259,909
18	.047	.001735	174	5.83	30.8	343,112
19	.041	.001320	132	4.44	23.4	450,856
20	.035	.000962	96	3.23	17.1	618,620
21	.032	.000804	80	2.70	14.3	740,193
22	.028	.000616	62	2.07	10.9	966,651
23	.025	.000491	49	1.65	8.71	......
24	.023	.000415	42	1.40	7.37	......
25	.020	.000314	31	1.06	5.58	......
26	.018	.000254	25	.855	4.51	......
27	.017	.000227	23	.763	4.03	......
28	.016	.000201	20	.676	3.57	......
29	.015	.000177	18	.594	3.14	......
30	.014	.000154	15	.517	2.73	......
31	.0135	.000143	14	.481	2.54	......
32	.013	.000133	13	.446	2.36	......
33	.011	.000095	9.5	.319	1.69	......
34	.010	.000079	7.9	.264	1.39	......
35	.0095	.000071	7.1	.238	1.26	......
36	.009	.000064	6.4	.214	1.13	......

This table was calculated on a basis of 483.84 pounds per cubic foot for steel wire. Iron wire is a trifle lighter.

The breaking strains were calculated for 100,000 pounds per square inch throughout, simply for convenience, so that the breaking strains of wires of any strength per square inch may be quickly determined by multiplying the values given in the table by the ratio between the strength per square inch and 100,000. Thus a No. 15 wire with a strength per square inch of 150,000 pounds has a breaking strain of $407 \times \frac{150,000}{100,000} = 610.5$ pounds.

It must not be thought from this table that steel wire invariably has a strength of 100,000 pounds per square inch. As a matter of fact it ranges from 45,000 pounds for soft annealed to over 400,000 pounds per square inch for hard wire.

STANDARD GAUGES.

No. of Gauge.	Thickness in Decimals of an Inch.							No. of Gauge.
	Birmingham.	Browne & Sharpe	U. S. Standard Plate Iron and Steel.	British Imperial.	Washburn & Moen Co.	Trenton Iron Co.	Stubs Steel Wire.	
7°	....	....	.500	.500	....	....	....	7°
6°	....	....	.46875	.464	....	....	....	6°
5°	....	....	.4375	.432	....	.45	....	5°
4°	.454	.46	.40625	.400	.3938	.40	....	4°
3°	.425	.40964	.375	.372	.3625	.36	....	3°
2°	.380	.3648	.34375	.348	.3310	.33	....	2°
0	.340	.32486	.3125	.324	.3065	.305	....	0
1	.300	.2893	.28125	.300	.2830	.285	.227	1
2	.284	.25763	.265625	.276	.2625	.265	.219	2
3	.259	.22942	.25	.252	.2437	.245	.212	3
4	.238	.20431	.234375	.232	.2253	.225	.207	4
5	.220	.18194	.21875	.212	.2070	.205	.204	5
6	.203	.16202	.203125	.192	.1920	.190	.201	6
7	.180	.14428	.1875	.176	.1770	.175	.199	7
8	.165	.12849	.171875	.160	.1620	.160	.197	8
9	.148	.11443	.15625	.144	.1483	.145	.194	9
10	.134	.10189	.140625	.128	.1350	.130	.191	10
11	.120	.090742	.125	.116	.1205	.1175	.188	11
12	.109	.080808	.109375	.104	.1055	.1050	.185	12
13	.095	.071961	.09375	.092	.0915	.0925	.182	13
14	.083	.064084	.078125	.080	.0800	.0800	.180	14
15	.072	.057068	.0703125	.072	.0720	.0700	.178	15
16	.065	.05082	.0625	.064	.0625	.0610	.175	16
17	.058	.045257	.05625	.056	.0540	.0525	.172	17
18	.049	.040303	.05	.048	.0475	.0450	.168	18
19	.042	.03589	.04375	.040	.0410	.0400	.164	19
20	.035	.031961	.0375	.036	.0348	.0350	.161	20
21	.032	.028462	.034375	.032	.03175	.0310	.157	21
22	.028	.025347	.03125	.028	.0286	.0280	.155	22
23	.025	.022571	.028125	.024	.0258	.0250	.153	23
24	.022	.0201	.025	.022	.0230	.0225	.151	24
25	.020	.0179	.021875	.020	.0204	.0200	.148	25
26	.018	.01594	.01875	.018	.0181	.0180	.146	26
27	.016	.014195	.0171875	.0164	.0173	.0170	.143	27
28	.014	.012641	.015625	.0148	.0162	.0160	.139	28
29	.013	.011257	.0140625	.0136	.0150	.0150	.134	29
30	.012	.010025	.0125	.0124	.0140	.0140	.127	30
31	.010	.008928	.0109375	.0116	.0132	.0130	.120	31
32	.009	.00795	.01015625	.0108	.0120	.0120	.115	32
33	.008	.00708	.009375	.0100	.0118	.0110	.112	33
34	.007	.006304	.00859375	.0092	.0104	.0100	.110	34
35	.005	.005614	.0078125	.0084	.0095	.0095	.108	35
36	.004	.005	.00703125	.0076	.0090	.0090	.106	36
37	....	.004453	.006640625	.0068	....	.0085	.103	37
38	....	.003965	.00625	.0060	....	.0080	.101	38
39	....	.003531	....	....	....	.0075	.099	39
40	....	.003144	....	....	....	.0070	.097	40

SIZE, WEIGHT, AND STRENGTH OF CHAINS.

Size, Inches.	Stud Link.			B. B. Crane.			B. B. B. Crane.			Best Special Dredge.		
	Weight per Fathom	Proof, Pounds.	Breaking Strain, Pounds.	Weight per Foot.	Proof, Pounds.	Breaking Strain, Pounds.	Weight per Foot.	Proof, Pounds.	Breaking Strain, Pounds.	Weight per Foot.	Proof, Pounds.	Breaking Strain, Pounds.
$\frac{3}{16}$	......	......	......	$\frac{11}{24}$	1,000	1,750	$\frac{11}{24}$	1,250	2,000	$\frac{11}{24}$	1,750	3,500
$\frac{1}{4}$	......	......	......	$\frac{3}{4}$	1,500	3,000	$\frac{3}{4}$	2,000	4,000	$\frac{3}{4}$	2,500	5,000
$\frac{5}{16}$	......	......	......	1	2,500	5,000	1	3,000	6,000	1	3,500	7,000
$\frac{3}{8}$	......	......	......	$1\frac{1}{2}$	4,000	8,000	$1\frac{1}{2}$	4,500	9,000	$1\frac{1}{2}$	5,000	10,000
$\frac{7}{16}$	......	......	......	2	6,000	12,000	2	6,500	13,000	2	7,000	14,000
$\frac{1}{2}$	......	......	......	$2\frac{1}{2}$	7,000	15,500	$2\frac{1}{2}$	8,000	17,000	$2\frac{1}{2}$	9,000	18,000
$\frac{9}{16}$	......	......	......	$3\frac{1}{6}$	9,000	18,000	$3\frac{1}{6}$	10,000	20,000	$3\frac{1}{6}$	11,000	22,000
$\frac{5}{8}$	......	......	......	$4\frac{1}{3}$	11,000	22,000	$4\frac{1}{3}$	12,000	26,000	$4\frac{1}{3}$	14,000	27,000
$\frac{11}{16}$	......	......	......	$5\frac{1}{3}$	14,000	28,000	$5\frac{1}{3}$	14,500	30,000	$5\frac{1}{3}$	17,000	32,500
$\frac{3}{4}$	34	20,250	32,000	$6\frac{1}{6}$	16,000	32,000	$6\frac{1}{6}$	17,500	36,000	$6\frac{1}{6}$	20,000	40,000
$\frac{13}{16}$	40	23.750	36,000	7	19,000	38,000	7	19,000	40,000	7	23,000	42,000
$\frac{7}{8}$	44	28,000	42,000	8	20,000	40,000	8	22,000	44,000	8	26,000	48,000
$\frac{15}{16}$	51	31,600	48,000	$9\frac{1}{6}$	24,000	48,000	$9\frac{1}{6}$	25,000	50,000	$9\frac{1}{6}$	29,000	54,000
1	59	36,000	54,000	$10\frac{1}{2}$	26,000	52,000	$10\frac{1}{2}$	28,000	57,000	$10\frac{1}{2}$	32,000	61,000
$1\frac{1}{16}$	66	40,600	62,000	12	28,000	56,000	12	32,000	65,000	12	35,000	69,000
$1\frac{1}{8}$	75	45,500	70,000	$13\frac{1}{6}$	32,000	60,000	$13\frac{1}{6}$	36,000	72,000	$13\frac{1}{6}$	40,000	78,000
$1\frac{3}{16}$	82	50,750	76,000	$14\frac{2}{3}$	36,000	72,000	$14\frac{2}{3}$	40,000	80,000	$14\frac{2}{3}$	46,000	88,000
$1\frac{1}{4}$	91	56,250	86,000	$16\frac{2}{3}$	42,000	84,000	$16\frac{2}{3}$	44,000	88,000	$16\frac{2}{3}$	51,000	95,000
$1\frac{5}{16}$	103	62,000	94,000	$17\frac{1}{2}$	46,000	92,000	$17\frac{1}{2}$	48,000	96,000	$17\frac{1}{2}$	54,000	104,000
$1\frac{3}{8}$	113	68,000	102,000	$19\frac{2}{3}$	50,000	100,000	$19\frac{2}{3}$	53,000	104,000	$19\frac{2}{3}$	58,000	114,000
$1\frac{7}{16}$	120	74,250	112,000	$21\frac{1}{6}$	54,000	108,000	$21\frac{1}{6}$	58,000	116,000	$21\frac{1}{6}$	62,000	122,000
$1\frac{1}{2}$	132	81,000	118,000	23	60,000	120,000	23	62,000	124,000	23	67,000	134,000

SIZE, WEIGHT, AND STRENGTH OF CHAINS—(*Continued*).

Size, Inches.	Stud Link.			B. B. Crane.			B. B. B. Crane.			Best Special Dredge.		
	Weight per Fathom	Proof, Pounds.	Breaking Strain, Pounds.	Weight per Foot.	Proof, Pounds.	Breaking Strain, Pounds.	Weight per Foot.	Proof, Pounds.	Breaking Strain, Pounds.	Weight per Foot.	Proof, Pounds.	Breaking Strain, Pounds.
$1\frac{9}{16}$	143	87,800	124,000	$25\frac{1}{6}$	64,000	128,000	$25\frac{1}{6}$	66,000	132,000	$25\frac{1}{6}$	70,500	142,000
$1\frac{5}{8}$	156	95,000	134,000	28	70,000	140,000	28	72,000	144,000	28	77,000	154,000
$1\frac{11}{16}$	162	102,500	144,000	......	......	......	......	......	......	30	79,000	158,000
$1\frac{3}{4}$	175	110,250	156,000	......	......	......	......	......	......	32	83,000	166,000
$1\frac{13}{16}$	189	118,250	166,000	......	......	......	......	......	......	33	89,000	178,000
$1\frac{7}{8}$	205	126,500	178,000	......	......	......	......	......	......	35	95,000	190,000
$1\frac{15}{16}$	222	135,000	190,000	......	......	......	......	......	......	38	101,000	202,000
2	240	144,000	202,000	......	......	......	......	......	......	40	108,000	216,000
$2\frac{1}{16}$	250	153,000	216,000	......	......	......	......	......	......	43	115,000	230,000
$2\frac{1}{8}$	265	162,500	228,000	......	......	......	......	......	......	47	122,000	244,000
$2\frac{3}{16}$	280	172,250	242,000	......	......	......	......	......	......	50	129,000	258,000
$2\frac{1}{4}$	300	182,250	256,000	......	......	......	......	......	......	53	136,500	273,000
$2\frac{3}{8}$	325	203,000	286,000	......	......	......	......	......	......	$58\frac{1}{2}$	152,000	304,000
$2\frac{1}{2}$	360	225,000	316,000	......	......	......	......	......	......	65	168,500	337,000
$2\frac{5}{8}$	400	241,800	340,000	......	......	......	......	......	......	70	181,000	362,000
$2\frac{3}{4}$	440	258,600	363,000	......	......	......	......	......	......	73	193,500	387,000
$2\frac{7}{8}$	475	275,200	386,000	......	......	......	......	......	......	76	206,000	412,000
3	520	291,600	410,000	......	......	......	......	......	......	86	218,000	436,000
$3\frac{1}{8}$	560	307,500	432,000									
$3\frac{1}{4}$	605	323,200	454,000									
$3\frac{3}{8}$	650	338,250	474,000									
$3\frac{1}{2}$	700	352,800	494,000									

NOTES ON ROOFS.

APPROXIMATE WEIGHT OF VARIOUS ROOF COVERINGS.

Material.	Weight in Pounds per Square of Roof.
Yellow pine (Northern) sheathing 1 inch thick.	300
" " (Southern).	400
Spruce.	200
Chestnut or maple.	400
Ash or oak.	500
Shingles, pine.	200
Slate $\frac{1}{4}$ inch thick.	900
Sheet iron $\frac{1}{16}$ inch thick.	300
" " $\frac{1}{16}$ inch " and laths.	500
Iron, corrugated	100 to 375
" galvanized, flat	100 to 350
Tin.	70 to 125
Felt and asphalt.	100
" " gravel.	800 to 1000
Skylights, glass, $\frac{3}{16}$ inch to $\frac{1}{2}$ inch thick.	250 to 700
Sheet lead.	500 to 800
Copper.	80 to 125
Zinc.	100 to 200
Tiles, flat.	1500 to 2000
" " with mortar.	2000 to 3000
" pan.	1000

ANGLES OF ROOFS AS COMMONLY USED.

Proportion of Rise to Span.	Angle.		Length of Rafter to Rise.	Proportion of Rise to Span.	Angle.		Length of Rafter to Rise.
	Deg.	Min.			Deg.	Min.	
$\frac{1}{2}$	45	..	1.4142	$\frac{1}{4}$	26	34	2.2361
$\frac{1}{3}$	33	41	1.8028	$\frac{1}{5}$	21	48	2.6926
$\frac{1}{2\sqrt{3}}$	30	..	2.0000	$\frac{1}{6}$	18	26	3.1623

APPROXIMATE LOADS PER SQUARE FOOT FOR ROOFS OF SPANS UNDER SEVENTY-FIVE FEET, INCLUDING WEIGHT OF TRUSS.

Roof covered with corrugated sheets, unboarded...	8	pounds.
" " " " " on boards......	11	"
" " " slate, on laths..................	13	"
Same, on boards 1¼ in. thick......................	16	"
Roof covered with shingles, on laths..............	10	"
Add to above, if plastered below rafters..........	10	"
Snow, light, weighs per cubic foot...........	5 to 12	"

For spans over 75 feet add 4 pounds to the above loads per square foot.

It is customary to add 30 pounds per square foot to the above for snow and wind when separate calculations are not made.

PRESSURE OF WIND ON ROOFS. (UNWIN.)

a = angle of surface of roof with direction of wind;
F = force of wind in pounds per square foot;
A = pressure normal to surface of roof $= F \sin a^{1.84 \cos a - 1}$.
B = pressure perpendicular to direction of wind $= F \cot a \sin a^{1.84 \cos a}$.
C = pressure parallel to direction of wind $= F \sin a^{1.84 \cos a}$.

Angle of roof = a........	5°	10°	20°	30°	40°	50°	60°	70°	80°	90°
$A = F \times$..............	.125	.24	.45	.66	.83	.95	1.00	1.02	1.01	1.00
$B = F \times$..............	.122	.24	.42	.57	.64	.61	.50	.35	.17	.00
$C = F \times$..............	.01	.04	.15	.33	.53	.73	.85	.96	.99	1.00

MISCELLANEOUS DATA.

FORCE OF THE WIND.

Description.	Miles per Hour.	Feet per Minute.	Feet per Second.	Force in Pounds per Sq. Foot.
Hardly perceptible..........	1	88	1.47	0.005
Just perceptible..........	2	176	2.93	0.02
	3	264	4.4	0.044
Gentle breeze..........	4	352	5.87	0.079
	5	440	7.33	0.123
Pleasant breeze..........	10	880	14.67	0.492
	15	1320	22	1.107
Brisk gale..........	20	1760	29.3	1.968
	25	2200	36.6	3.075
High wind..........	30	2640	44	4.428
	35	3080	51.3	6.027
Very high wind..........	40	3220	58.6	7.872
	45	3960	66	9.963
Storm..........	50	4400	73.3	12.300
Great storm..........	60	5280	88	17.712
	70	6160	102	24.108
Hurricane or cyclone..........	80	7040	117.3	31.488
	100	8800	146.6	49.200

MELTING-POINTS OF METALS.

Metals.	Centigrade, Degrees.	Fahrenheit, Degrees.	Metals.	Centigrade, Degrees.	Fahrenheit, Degrees.
Aluminum........	700	1292	Lead........	334	617
Antimony........	425	797	Magnesium........	235	455
Arsenic........	185	365	Mercury........	40	40
Bismuth........	264	507	Nickel........	1600	2912
Cadmium........	320	608	Potassium........	62	143
Cobalt........	1200	2192	Platinum........	2600	4712
Copper........	1091	1995	Silver........	1040	1944
Gold........	1381	2485	Steel........	1400	2552
Indium........	176	348	Sodium........	96	173
Iron, wrought...	1500	2786	Tin........	235	455
Iron, cast........	1200	2192	Zinc........	412	774

COLOR OF HOT METALS AND TEMPERATURE AT CERTAIN COLORS.

Color.	Corresponds to	
	Centigrade, Degrees.	Fahrenheit, Degrees.
Incipient red heat..........	525	977
Dull red..........	700	1292
Incipient cherry-red..........	800	1472
Cherry-red..........	900	1652
Clear cherry-red..........	1000	1832
Deep orange..........	1100	2012
Clear orange..........	1200	2192
White..........	1300	2372
Bright white..........	1400	2552
Dazzling white..........	1500	2732

To find the weight of metal objects: Measure the number of cubic inches contained in the piece and multiply by 0.2816 for wrought iron, 0.2607 for cast iron, 0.32418 for copper, 0.41015 for lead, 0.3112 for brass, and the answer will be the number of pounds in the piece.

MOULDERS AND PATTERN-MAKERS' TABLE.

White Pine being 1.		Cast Iron being 1.		Bar Iron being 1.	
Cast iron	13	Bar iron	1.07	Cast iron	.95
Copper	13.4	Steel	1.08	Steel	1.03
Brass	12.7	Brass	1.16	Copper	1.16
Lead	18.1	Copper	1.21	Brass	1.09
Steel	14	Lead	1.55	Lead	1.48

SHRINKAGE IN CASTINGS.

Pattern-makers' rule.	Aluminum	$\frac{3}{16}$ inch per foot.
	Cast iron	$\frac{1}{8}$ " " "
	Brass	$\frac{3}{16}$ " " "
	Copper	$\frac{3}{16}$ " " "
	Lead	$\frac{1}{8}$ " " "
	Steel	$\frac{1}{4}$ " " "
	Tin	$\frac{1}{12}$ " " "
	Zinc	$\frac{3}{16}$ " " "

Reduction for Round Cores and Core-prints.—*Rule.*—Multiply the square of the diameter by the length of the core in inches and the product multiplied by 0.017 is the weight of the pine core to be deducted from the weight of the pattern

WEIGHT OF CAST-IRON SASH-WEIGHTS.

Length in Inches.	Round. Inches in Diameter.								
	1	1¼	1½	1¾	2	2¼	2½	2¾	3
	Weight in Pounds.								
1	.20	.31	.45	.62	.81	1.04	1.27	1.53	1.83
2	.40	.62	.90	1.24	1.62	2.08	2.54	3.06	3.66
3	.60	.93	1.35	1.86	2.43	3.12	3.81	4.59	5.41
4	.80	1.24	1.80	2.48	3.24	4.16	5.08	6.12	7.32
5	1.00	1.55	2.25	3.10	4.05	5.20	6.35	7.65	9.15
6	1.20	1.86	2.70	3.72	4.86	6.24	7.62	9.18	10.98
7	1.40	2.17	3.15	4.34	5.67	7.28	8.89	10.71	12.81
8	1.60	2.48	3.60	4.96	6.48	8.32	10.16	12.24	14.64
9	1.80	2.79	4.05	5.58	7.29	9.36	11.43	13.77	16.47
10	2.00	3.10	4.50	6.20	8.10	10.40	12.70	15.30	18.30
11	2.20	3.41	4.96	6.88	9.91	11.44	13.97	16.83	20.13
12	2.43	3.72	5.40	7.44	9.72	12.48	15.24	18.36	21.96

Length in Inches.	Square. Inches Square.								
	1	1¼	1½	1¾	2	2¼	2½	2¾	3
	Weight in Pounds.								
1	.26	.40	.58	.79	1.04	1.31	1.62	1.96	2.34
2	.52	.80	1.16	1.58	2.08	2.62	3.24	3.92	4.68
3	.78	1.20	1.74	2.37	3.12	3.93	4.86	5.88	7.02
4	1.04	1.60	2.32	3.16	4.16	5.24	6.48	7.84	9.36
5	1.30	2.00	2.90	3.95	5.20	6.55	8.10	9.88	11.70
6	1.56	2.40	3.48	4.74	6.24	7.86	9.72	11.76	14.04
7	1.82	2.80	4.06	5.53	7.28	9.17	11.34	13.72	16.38
8	2.08	3.20	4.64	6.32	8.32	10.48	12.96	15.68	18.72
9	2.34	3.60	5.22	7.11	9.36	11.79	14.58	17.64	21.06
10	2.60	4.00	5.88	7.90	10.40	13.10	16.20	19.60	23.40
11	2.86	4.40	6.38	8.69	11.44	14.41	17.82	21.56	25.74
12	3.12	4.80	6.96	9.48	12.48	15.72	19.44	23.52	28.08

WEIGHT OF CROWDS.—The weight of crowds on floors per square foot varies from 100 to 145 pounds. Prof. Kernot of Victoria made some experiments with a crowd of persons in which he packed them close enough to give a weight on the floor of 147.4 pounds per square foot.

Miscellaneous Materials.—GLUE.—This valuable product consists essentially of gelatine and is prepared from a variety of animal products. It varies in purity and in quality

TABLE OF LEAD SASH-WEIGHTS.

Size.	Round Weights, Weight per Lineal Foot.	Square Weights, Weight per Lineal Foot.
1 inch	3½ pounds	4.93 pounds
1¼ "	6 "	7.68 "
1½ "	8¼ "	10.27 "
1¾ "	11¾ "	15.08 "
2 "	15½ "	19.02 "
2¼ "	18½ "	24 "
2½ "	23 "	30.82 "
3¾ "	28.93 "	37.27 "
3 "	34.81 "	44.38 "
3¼ "	40.52 "	52.07 "
3½ "	47.26 "	60.82 "
3¾ "	54 "	69.33 "
4 "	61.93 "	

from the almost colorless varieties of gelatine or fish glue to the dark-brown color.

Glue is made by digesting bones and other animal tissues at a low temperature (best in a vacuum apparatus), then clarifying the liquid from any insoluble portions, and setting this in moulds to cool; when cold, cutting it into thin slices and exposing these on netting until dry. The palest glues are made from the best materials, and the hot liquids are bleached. The darkest glues are usually made from bones and are not treated before drying.

The best glues are transparent and of a clear amber color. When glue is prepared it should be broken up and allowed to stand overnight in cold water. It should be melted in a double pot and covered to keep out all dirt. The water in the outer pot should always be high enough to be above the glue in the small pot.

Glue that has been remelted several times loses its strength. Glue should be used when it is boiling hot, and the pieces to be glued together should be heated and the glue spread on them in a thin film; then the pieces should be clamped together tight enough to force out all surplus glue.

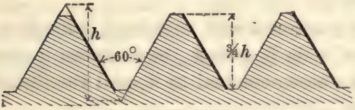
Alum.—Alum is a whitish, astringent, saline substance; properly it is a double salt, being composed of sulphate of potash and sulphate of alumina, which, along with a certain proportion of water, crystallize together in cubes.

It is soluble in eighteen times its weight in cold water, and in its own weight of hot water. The solution thus obtained has a peculiar astringent taste, and is strongly acid to colored test-papers.

STANDARD SCREW-THREADS, NUTS, AND BOLT-HEADS.

Recommended by the Franklin Institute.

SCREW-THREADS.



Angle of thread 60°. Flat at top and bottom $= \frac{1}{8}$ of pitch.

Diameter of Screw, Inches.	Diameter at Root of Thread, Inches.	Threads per Inch, Number.
$\frac{1}{4}$	.185	20
$\frac{5}{16}$	.240	18
$\frac{3}{8}$	.294	16
$\frac{7}{16}$	.344	14
$\frac{1}{2}$	.400	13
$\frac{9}{16}$	.454	12
$\frac{5}{8}$	.507	11
$\frac{3}{4}$	.620	10
$\frac{7}{8}$	.731	9
1	.837	8
$1\frac{1}{8}$	.940	7
$1\frac{1}{4}$	1.065	7
$1\frac{3}{8}$	1.160	6
$1\frac{1}{2}$	1.284	6
$1\frac{5}{8}$	1.389	$5\frac{1}{2}$
$1\frac{3}{4}$	1.490	5
$1\frac{7}{8}$	1.615	5
2	1.712	$4\frac{1}{2}$
$2\frac{1}{4}$	1.962	$4\frac{1}{2}$
$2\frac{1}{2}$	2.175	4
$2\frac{3}{4}$	2.425	4
3	2.629	$3\frac{1}{2}$
$3\frac{1}{4}$	2.879	$3\frac{1}{2}$
$3\frac{1}{2}$	3.100	$3\frac{1}{4}$
$2\frac{3}{4}$	3.317	3
4	3.567	3
$4\frac{1}{4}$	3.798	$2\frac{7}{8}$
$4\frac{1}{2}$	4.028	$2\frac{3}{4}$
$4\frac{3}{4}$	4.255	$2\frac{5}{8}$
5	4.480	$2\frac{1}{2}$
$5\frac{1}{4}$	4.730	$2\frac{1}{2}$
$5\frac{1}{2}$	4.953	$2\frac{3}{8}$
$5\frac{3}{4}$	5.203	$2\frac{3}{8}$
6	5.423	$2\frac{1}{4}$

Nuts and bolt-heads are determined by the following rules, which apply to both square and hexagon nuts:

Short dia. of rough nut $= 1\frac{1}{2} \times$ dia. of bolt $+ \frac{1}{8}$ in.

Short dia. of finished nut $= 1\frac{1}{2} \times$ dia. of bolt $+ \frac{1}{16}$ in.

Thickness of rough nut = dia. of bolt.

Thickness of finished nut = dia. of bolt $- \frac{1}{16}$ in.

Short dia. of rough head $= 1\frac{1}{2} \times$ dia. of bolt $+ \frac{1}{8}$ in.

Short dia. of finished head $= 1\frac{1}{2} \times$ dia. of bolt $+ \frac{1}{16}$ in.

Thickness of rough head $= \frac{1}{2}$ short dia. of head.

Thickness of finished head = dia. of bolt $- \frac{1}{16}$ in.

The long diameter of a hexagon nut may be obtained by multiplying the short diameter by 1.155 and the long diameter of a square nut by multiplying the short diameter by 1.414.

The above standards for screw-threads, nuts, and bolt-heads were recommended by the Franklin Institute in December, 1864. The standard for screw-threads has been very generally adopted in the United States, but the proportions recommended for nuts and bolt-heads have not found general acceptance because of the odd sizes of bar—not usually rolled by the mills—required to make the nut.

Alum is made by digesting aluminous earths with sulphuric acid, treating the mass with water, and adding to the solution potassium sulphate, after which it is allowed to crystallize out.

The manufacture of the colors or paints called lakes depends on this property of alumina to attach to itself certain coloring-matters.

Thus, if a solution of alum is colored with cochineal or madder, and ammonia or carbonate of soda is added, the alumina in the alum is precipitated with the color attached to it, and the liquid is left colorless.

It is commonly used by paperhangers to keep paste sweet.

Ammonia.—Ammonia is the solution of gas ammonia in water. Ammonia gas is composed of 1 part nitrogen and 3 parts hydrogen.

Ammonia is a volatile liquid, characterized by a strong, peculiar odor, and evaporates completely away when exposed to air or boiled. It is a powerful base, uniting with and neutralizing all acids, and will dissolve many gums and acids.

It is used as a powerful cleaner for glass or woodwork when diluted to a light solution. Especially useful in fairly strong solution, cleaning floors where revarnishing is to be done.

Whiting.—This pigment is prepared from chalk. Chalk is a natural deposit of calcium carbonate, found extensively in England and France. When chalk is examined under a microscope it is seen to consist of minute shells, the remains of a group of animals known as Foraminifera, of which there are many species. These form a skeleton of calcium carbonate. They live on the surface of the sea. Whiting is nothing more than chalk ground up with water. Whiting is largely used as a body color in distemper work, using water as a vehicle. It is quite permanent when used as a pigment, resisting exposure to all ordinary atmospheric conditions.

Asphaltum.—This substance is employed in the preparation of varnishes such as black japan. It was originally obtained from the shores of the Dead Sea. It is imported from Egypt, South America, and is found in a few places in the United States. The exact chemical composition has not yet been ascertained; presumably allied to petroleum and the paraffines.

Artificial asphaltum is made by melting or mixing together rosin, coal-tar, wood, and other pitches, and is used in preparing cheap black varnishes.

Beeswax.—This is the best known of waxes and is the prod-

uct of various species of insects belonging to the genus Apis which are found in every quarter of the globe.

The wax is obtained by melting the combs in water and then allowing the molten wax to cool.

ALCOHOL.—It is a limpid, colorless liquid of a hot, pungent taste, and having a slight but agreeable smell. Owing to its extensive application, it becomes one of the most important substances produced by art.

There is only one source of alcohol, namely, the fermentation of sugar and other saccharine matter. The best vegetable substances for yielding it are those that contain the greatest abundance of sugar or starch.

Owing to the attraction of alcohol for water, it is impossible to procure pure alcohol by distillation alone.

Alcohol has the property of non-freezing. This property of non-freezing at any degree of cold to which the earth is subjected has led to the employment of alcohol colored by red cochineal in the thermometers sent out to the Arctic regions.

It is a powerful solvent for acids, resins, gums, oils, and waxes, and hence is employed in the preparation of varnishes. On account of rapid evaporation it is especially used in making shellac varnish.

It acts as a poison by abstracting the water from the parts it touches. It is highly inflammable, its combustion yielding only carbonic acid and water.

GRAPHITE.—Silica-graphite is as pure and sweet as charcoal, is mined at Ticonderoga, N. Y., and is an ideal pigment in flake form.

Graphite possesses greater affinity for iron and steel than any other pigment. Silica-graphite, while smooth and slippery and apparently oily to touch, is absolutely free from any oil or grease. In this respect it differs entirely from lampblack and similar products.

It is an ideal protective coating for all kinds of metal or wood. It lasts four or five times longer than any other paint, and covers two or three times more surface. It is also easier to apply than any other paint and wears brushes less.

This silica-graphite is used on new and old work, should be used for all priming or first coats, and can be used on top of any old paint. This paint has no bad odor, and will not taint water, and is as pure and sweet and healthful as charcoal, containing nothing poisonous. Good for inside of water-tanks.

It has twice the bulk of mineral paint, therefore covers just so much more surface, and is applied and used the same as linseed-oil paint.

Graphite is equally useful for wood or metal, and never fades, therefore stands without a rival for durability, economy, and for beauty of finish.

MURIATIC ACID.—Muriatic acid is prepared by heating common salt with sulphuric acid, dissolving the evolved gas in water. When pure it is a colorless liquid, fuming slightly and having a strong acid smell.

Muriatic acid is a powerful acid. It dissolves in the cold such metals as zincs, iron magnesium, nickel, and aluminum. When boiling it dissolves tin, lead, copper, bismuth, and many other metals. Muriatic acid is used largely in cleaning the alkali collecting on brick or stone buildings.

OXALIC ACID.—Oxalic acid was first discovered in the juice of the Oxalis acetosella. It is widely distributed in the vegetable kingdom in the form of potassium, sodium, and calcium salts, and is made artificially by heating sawdust with a mixture of caustic potash and soda. It forms white crystals, is readily soluble in water and alcohol, has an intensely acid taste, and is violently poisonous. It is often sold under the erroneous name of salts of lemon. Oxalic acid is largely used in calico-printing dyeing, and in bleaching flax and straw. It is used by painters in bleaching floors and woodwork.

GYPSUM.—Gypsum is used principally for wall plaster, and the most important markets are the large cities in which modern buildings are being constructed. Gypsum plaster is largely displacing lime mortar as wall finish. Not only is it found to be more suitable and durable, but its strength and hardness, and the fact that construction can be completed more quickly when it is used, have brought it into favor.

In the Rocky Mountain States and the region westward to the Pacific coast, the gypsum industry is in its infancy. There are plants in Montana, in the Black Hills of South Dakota, in Wyoming, Colorado, New Mexico, Utah, Nevada, California, and Oregon. Some of them have a large capacity, and their product is finding a ready market. This is more particularly true of those which supply the larger cities. The deposits are well distributed in these States, and the character of the gypsum is such that they can meet any requirements of the trade. No doubt the industry will advance with the growth of the country, and when the value of gypsum plaster is better appreciated

it will displace the lime and sand plaster in these States, as it is doing in the East.

STAFF.—This composition, which was used so extensively in the construction of buildings for the Chicago Exposition, and has been employed even more extensively in the buildings for the St. Louis Exposition, is a mixture of ordinary plaster of Paris with a suitable binding material. The latter must be rather coarse and loose, to allow the plaster to percolate through it and afford the necessary surface for adhesion. Manila fibre, hemp, etc., are commonly used for a binder. As a building material staff is well-nigh fire-proof. Frost does not hurt it. Rain as little effect upon it. A drip injures it. The short durability of staff plaster on exposition buildings in some instances has been due to their inadequate foundations and the shrinkage of the sheeting to which the plaster is applied. If spread on expanded metal lathing, staff plaster would doubtless prove durable. Staff and cement do not give a good mixture.

SILICATE STONE.—This is an English invention and consists essentially of silica and lime. The proportion of lime used is from 5 to 10 per cent, the purity of the silica regulating the quantity. When the proper mixture has been made it is put into moulds, water and steam are injected, and the whole subjected to a high heat and pressure. In this way, it is stated, the lime combines with part of the sand and forms a silicate of lime, to the presence of which the mechanical strength of the stone is principally due. The crushing strength is given as 10,776 pounds per square inch. The process takes six hours from the time the mixture enters the moulds until it is ready for shipment. In appearance the stone resembles granite, though the color can be changed in manufacturing to suit the taste of customers. It is adapted to working in intricate ornamental designs, and is claimed to have the property of resisting the injurious action of salt or fresh water and varying atmospheric conditions.

BUILDING PAPERS.—There are a number of different building papers on the market, such as asbestos, parchment, felt, rosin-sized, asphalt, tar, etc.

They are usually graded as to weight or thickness.

The felt or deafening papers are usually graded as to weight per square yard, and generally come in three weights, viz.: 9 square feet to a pound, and which is about $\frac{3}{64}$ inch in thickness; 6

square feet to a pound, and which is about $\frac{1}{16}$ inch in thickness; $4\frac{1}{2}$ square feet to a pound, and which is about $\frac{5}{64}$ inch in thickness.

The asbestos papers usually run in three thicknesses as follows: Thin, which weighs 6 pounds per 100 square feet and which is about $\frac{1}{100}$ inch in thickness; medium, which weighs 10 pounds per 100 square feet, and which is about $\frac{1}{64}$ inch in thickness; and heavy, weighing 14 pounds per 100 square feet, and which is about $\frac{1}{40}$ inch in thickness.

Rosin-sized papers also come in various thicknesses, but are usually very thin; they are made by immersing Manila or other paper in a mixture of rosin, glue, and ochre.

Asphalt papers are made by saturating felt paper with asphaltum, either alone or mixed with petroleum residuum.

The various tar and roofing papers are made in one, two, or three thicknesses, and are designated as "one-ply," "two-ply," etc.

Asbestos.—This is a mineral of so fibrous a nature that it can be woven into a textile fabric, which is naturally incombustible, having also the quality of slow conduction of heat. Its chief use in building has been for covering of steam-pipes, deafening for floors, sheathing paper, etc.

Its color ranges from white, through many shades of yellow to a dull brown.

Coal-tar.—Coal-tar is a by-product produced in the manufacture of coal-gas. When distilled it produces, in various stages, coal-naphtha, dead oil or creosote, and tar or pitch; this last is used for roofing, waterproofing, etc. Coal-tar after being distilled is very brittle at the freezing-point, and softens and flows between 70° and 115° Fahr.

Paving pitch is the residue obtained from distilling coal-tar.

Creosote-oil is a product obtained in distilling coal-tar. It is mostly used for preserving timber.

Asphaltum and Bituminous Rock.—The general term "asphaltum" may be applied to the numerous varieties of hydrocarbons of an asphaltic base which exist in all conditions, from the liquid to the solid state. The general rule has been to include under asphaltum only material used as such, for instance, the residuum from petroleum-refining processes which is sold and used as asphalt.

The term "bituminous rock" includes sandstones and limestones impregnated with asphaltum or bitumen which are shipped and sold without previous mixing. This rock is used prin-

pally for street pavement, and is either used in its natural state or mixed with other ingredients.

Bituminous rock is also treated to obtain asphaltum or bitumen, the product being sold as refined or gum asphalt.

Asphaltum is much used for roofing purposes, and is much superior to the ordinary tar or pitch, as the sun and weather does not affect it.

When there is any doubt as to the composition of either asphaltum or bituminous rock, a careful analysis should be made.

Mineral Wool is essentially a vitreous substance converted to a fibrous condition. In appearance it consists of a mass of very fine fibres interlacing each other in every direction, thus forming an innumerable number of minute air-cells. The resemblance of these fibres to those of wool or cotton has given to the material the name of mineral wool in this country, and of silicate cotton elsewhere; but it is only in appearance and softness that any similarity exists between the mineral and organic fibres.

Mineral wool partakes of the nature of glass without its brittleness, the fibres being soft, pliant, and inelastic. They are of irregular thickness, and cross each other in all possible directions. It is made by converting scoria and certain rocks, while in a melted condition, to a fibrous state.

Average Weight.	Pounds per Cubic Foot.	Square Foot One Inch Thick.	Cubic Feet to Ton.
Ordinary slag wool	12	1 pound	166
Selected " "	9	¾ "	223
Extra " "	6	½ "	333
Ordinary rock wool	12	1 "	166
Selected " "	8	⅔ "	250
Extra " "	6	½ "	333

Litharge.—Obtained by melting lead and passing a current of air over the molten lead. The oxygen is absorbed; the resulting oxide is allowed to melt and run into suitable vessels. On cooling it breaks into fragments, which are again broken into flakes or powdered, as the case may be, and ready for the market.

Litharge is used for a great variety of purposes: in making glass, cements, colors, pottery, calico-printing, and as a dryer in paints and oils, etc.

Mica.—Common mica is a double silicate of potash and

alumina. A characteristic feature of mica is that it occurs in plates which are readily split into thin transparent slices, with great power of resisting heat. Mica forms one of the constituents of a typical granite, and it appears in small flakes throughout the stone.

Miscellaneous Receipts. — TEST FOR SEWER-GAS. — Saturate unglazed paper with a solution of 1 ounce pure lead acetate in half a pint of rain-water; let it partially dry, then expose in the room suspected of containing sewer-gas.

The presence of gas in any considerable quantity soon darkens or blackens the test-paper. A suspected joint of a pipe can be tested by wrapping with a single layer of white muslin, moistened with the above solution, and if gas is escaping it will darken the cloth.

TO CLEAN COPPER.—Take 1 ounce of oxalic acid, 6 ounces of rotten stone, ½ ounce of gum arabic, all in powder, 1 ounce of sweet-oil, and sufficient water to make a paste. Apply a small portion and rub dry with a flannel or leather.

REMOVAL OF STAINS FROM GRANITE. —A paste of 1 ounce of ox-gall, 1 gill of strong solution of caustic soda, 1½ tablespoonfuls of turpentine, with enough pipe-clay to make it thick, and scour well.

Or, mix together ¼ pound soft soap, 1 ounce washing-soda, and a piece of sulphate of soda as big as a walnut. Rub it over the surface proposed to clean, let it stand twenty-four hours, and then wash off; or, smoke and soot stains can be removed with a hard scrubbing-brush and fine sharp sand, to which add a little potash.

Or, use strong lye, or make a hot solution of 3 pounds of common washing-soda dissolved in 1 gallon of water. Lay it on the granite with a paint-brush.

TO CLEAN MARBLE.—Mix 2 parts by weight of sal-soda, 1 part powdered chalk or fine bolted whiting, and 1 part powdered pumice-stone with enough water to make a thin batter, and by the means of a scrubbing-brush apply it to the spots; then wash off with soap and water.

Or, to remove grease spots from marble, moisten fine whiting or fullers' earth with benzine, apply it in a thick layer to the spots, and let it remain for some time; then remove the dry paste and wash the spot with soap and water.

To extract oil stains from marble, make a paste by mixing 2 parts of fullers' earth, 1 part soft soap, and 1 part potash with

boiling water. Apply this paste to the spots and let it remain three or four hours.

To Remove Paint from Window Glass.—Put sufficient saleratus into hot water to make a strong solution, and with this saturate the paint which adheres to the glass. Let it remain until nearly dry, then rub it off with a woollen cloth.

To Make Modelling Clay.—Knead dry clay with glycerine instead of water, work thoroughly with the hands, moisten work at intervals of two or three days, and keep covered to prevent evaporation of moisture.

To Clean Paint.—When paint is washed with any strong alkaline solution, such as soda or strong soap, the oil of the paint is liable to be changed to soap and the paint is seriously injured. To avoid this, take some of the best whiting, and have ready some clean warm water and a piece of flannel, which dip into the water and squeeze nearly dry; then take up as much whiting as will adhere to it, apply it to the painted surface, when a little rubbing will quickly remove any dirt or grease stains. After this wash the part well with clean water, rubbing it dry with a soft chamois. Paint thus cleaned will look as well as when first put on, and the operation may be tried without fear of injury to the most delicate colors. It answers far better than the use of soap, and does not require more than one-half the time and labor. Another simple method is the following: Put a tablespoonful of aqua ammonia in a quart of moderately hot water, dip in a flannel cloth, and with this merely wipe over the surface of the woodwork. No rubbing is necessary. The first recipe is preferable, except where the paint is badly discolored.

To Age or Color Copper.—Add about 1 pound of powdered sal ammoniac to 5 gallons of water, dissolve it thoroughly, and let it stand at least twenty-four hours before putting it on the copper. Apply it to the copper with a brush, being sure to cover every place; let it stand for a day and sprinkle with water, using a brush to sprinkle the water on so that it will not run and streak the copper. After standing overnight the color will be as desired. The same effect can be produced by using vinegar and salt instead of the sal ammoniac, using ½ pound of salt to 2 gallons of vinegar.

To Remove Old Glass from Sash.—Take a hot iron and run along the surface of the putty, when it can easily be removed with a chisel.

To Remove Rust Stains.—To remove rust stains from wood, wash the disfigured parts with a solution of 2 ounces of oxalic acid to 1 pint of hot water.

In fitting doors, always keep the hollow side next the stop or rebate strip.

A flour barrel is 28 to 30 inches high and 20 to 21 inches in diameter.

When hanging transoms, where possible, if the transom is to be hung at the top, hang them so that when they are open the glass will lay on the wood and not on the putty.

Wash-stands are usually set 2 feet 6 inches from the floor.

The relative strength of timbers is estimated by multiplying the breadth by the square of the depth. *Example.*—How many times as strong is a joist $2\frac{1}{2}'' \times 15''$ when supported on its narrow side as when supported on its broad side: $2\frac{1}{2} \times 2\frac{1}{2} = 6\frac{1}{4}$, $6\frac{1}{4} \times 15 = 93\frac{7}{10}$, $15 \times 15 = 225$, $225 \times 2\frac{1}{2} = 562\frac{1}{2}$, $562\frac{1}{2} \div 93\frac{7}{10} = 6$, or six times stronger.

GLOSSARY OF NAMES OF SOME NEW MATERIALS USED IN BUILDING.

Alaster. A fire-proof paint, manufactured by the National Fireproof Paint Corporation, Chicago, Ill.

Æolipile. A patent damper for use in the smoke-collar of a furnace, manufactured by the Æolipile Co., New York.

Ab-lu-ent. A paint and varnish remover, manufactured by the Detroit White Lead Works, Detroit, Mich.

Anhydrosal. A water-proof coating for concrete and brick, manufactured by Toch Bros., New York.

Asbestolith. A plastic sanitary floor covering, manufactured by the Asbestolith Co., New York.

Asbestoside. A siding for buildings, manufactured by H. W. Johns-Manville Co., New York

Alabastine. An interior-wall paint, manufactured by the Alabastine Co., Grand Rapids, Mich.

Alphaduct. A flexible conduit for electric wires, manufactured by the Alphaduct Mfg. Co., New York.

Asbestine. A fire-proof paint, manufactured by the Alden Spears Sons Co., New York.

Anaglypta. An embossed-paper wall covering, for sale by W. H. S. Lloyd Co., New York.

APADAC. A structural-meal paint, manufactured by the Chilton Paint Co., New York.

BITULITHIC PAVEMENT. A pavement put down by Warren Bros., New York.

BESSEMER PAINT. A paint for the protection of iron and steel, manufactured by Rinald Bros., Philadelphia, Pa.

CARBOLINEUM AVENARIUS. A wood-preserving paint, manufactured by the Carbolineum Wood-preserving Co., New York.

CEMENTICO. A cold-water paint, manufactured by the U. S. Gypsum Co.

CONSERVO. A wood preservative, manufactured by Samuel Cabot, Boston, Mass.

CALSOM FINISH. A kalsomine for interior walls, manufactured by B. Moore, Chicago, Ill.

DULL-EINE. A dull varnish, manufactured by Samuel F. Woodhouse, Philadelphia, Pa.

FLINTKOTE. A prepared roof covering, manufactured by J. A. Bird & Co., Boston, Mass.

FLINTOLINE. A floor paint, manufactured by F. W. Devoe Co., Chicago, Ill.

FLUATE (Lockpore). A coating for the preservation of marble, stone, terra-cotta, etc., manufactured by Toch Bros., New York.

GRAINOLETTE. A transfer graining paper, manufactured by the Stencil Treasury, 209 E. 59th St., New York.

HYDREX. A water-proofing compound, manufactured by F. W. Bird & Son, East Walpole, Mass.

INDURINE. A cold-water paint, manufactured by L. A. Moore & Co., St. Paul, Minn.

JAP-A-LAC. A floor finish or varnish, manufactured by the Gilden Varnish Co., Cleveland, Ohio.

KALLIGRAIN. A transfer graining paper, manufactured by Emil Majert, New York.

KONKERIT COATING. A water-proof paint for concrete or brick walls, manufactured by Toch Bros., New York.

LINOFELT. A sheathing fibre felt, manufactured by Union Fibre Co., Winona, Minn.

LYTHITE. A white enamel paint, manufactured by Frank S. De Ronde Co., New York.

LETHEROID. A wool-felt roof covering, manufactured by the Union Paper Co., Cleveland, Ohio.

MARBELITHIC. An artificial marble, made by the Marbelithic Co., Dayton, Ohio.

MONOLITH. A sanitary plastic flooring, base, etc., manufactured by the American Monolith Co., Milwaukee, Wis.

MALTHOID. A ready roofing, manufactured by the Paraffine Paint Co., San Francisco, Cal.

MIRAC. A varnish and paint remover, manufactured by J. Lucas & Co., Philadelphia, Pa.

MURA-KALSO. A kalsomine, manufactured by American Lucol Co., New York.

METILE. A metal wall covering in imitation of tile, manufactured by Wisconsin Mantel Co., Milwaukee, Wis.

NOVUS GLASS. A glass wainscot, etc., manufactured by the Penn-American Plate Glass Co., Pittsburg, Pa.

OKONITE. A brand of insulated electric-light wire, manufactured by the Okonite Co., Broadway, New York.

PORCELITE. A white-enamel paint, manufactured by the Thomson Wood Finishing Co., Philadelphia, Pa.

PHENOID. A varnish and paint remover, manufactured by Ellis Chambers, Dedham, Mass.

ROOF-LEAK. An asphalt roof coating, manufactured by the Elliot Varnish Co., Chicago, Ill.

SUPERBA. A cold-water paint, or kalsomine for interior walls, manufactured by the Dry Kalsomine and Paint Works, New York.

SIAMLAC. A substitute for shellac, sold by J. B. Moffett, Minneapolis, Minn.

SILICATED CARBON. A transparent waterproofing for concrete and brick, manufactured by the Standard Specialty Co., Cleveland, Ohio.

SPHINX GUM. A strengthener to add to flour paste, manufactured by the Arabol Manufacturing Co., 100 William Street, New York.

SALSEE. A plastering fibre used in place of hair, manufactured by C. R. Weeks, 14th Street, New York.

SACKET'S PLASTER BOARD. A plaster board made in sheets 32″×36″ and nailed to the studs, and then finished with a coat of hard plaster, sold by the Garden City Sand Co., Chicago, Ill.

SANITAS. A cloth wall covering, manufactured by the Standard Table Oil Cloth Co., New York.

TAPESTROLA. A burlap decoration, manufactured by Richter Manufacturing Co., Tenafly, N. J.

TITEKOTE. An iron-preservative paint, manufactured by the Barber Asphalt Co., Philadelphia, Pa.

TEX-TA-DOR-NA. A burlap wall covering, manufactured by the Tex-ta-dor-na Manufacturing Co., Columbus, Ohio.

TRANSITE. A fire-proof lumber, manufactured by H. W. Johns-Manville Co.

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